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Singh et al.

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(54) **METHOD AND SYSTEM FOR UNIFIED TECHNOLOGICAL STACK MANAGEMENT FOR RELATIONAL DATABASES**

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G06F 7/00 (2006.01)

(52) **U.S. Cl.**
CPC ... ***G06F 17/30289*** (2013.01); *G06F 17/30174* (2013.01); *G06F 17/30575* (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30575; G06F 17/30174; G06F 17/30289; G06F 17/30292; G06F 17/30864; G06F 17/30339; G06F 17/30312; G06F 17/30321; G06F 17/30917; G06F 17/30091; G06F 17/30336
See application file for complete search history.

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Primary Examiner — Dung K Chau

(57) **ABSTRACT**

An approach is described for providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes. The approach includes creating a global storage instance, wherein the global storage instance contains metadata for a storage layer including a plurality of storage nodes, and wherein the global storage instance is delocalized from the plurality of storage nodes. The approach also includes receiving a database operation request from an operating system layer. The approach further includes mediating the database operation request between the operating system layer and the storage layer using the global storage instance.

14 Claims, 20 Drawing Sheets

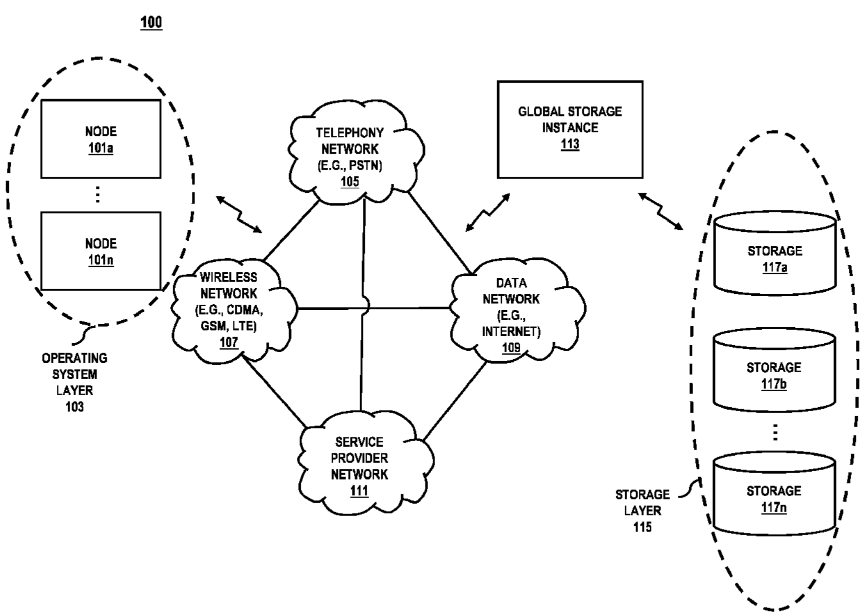
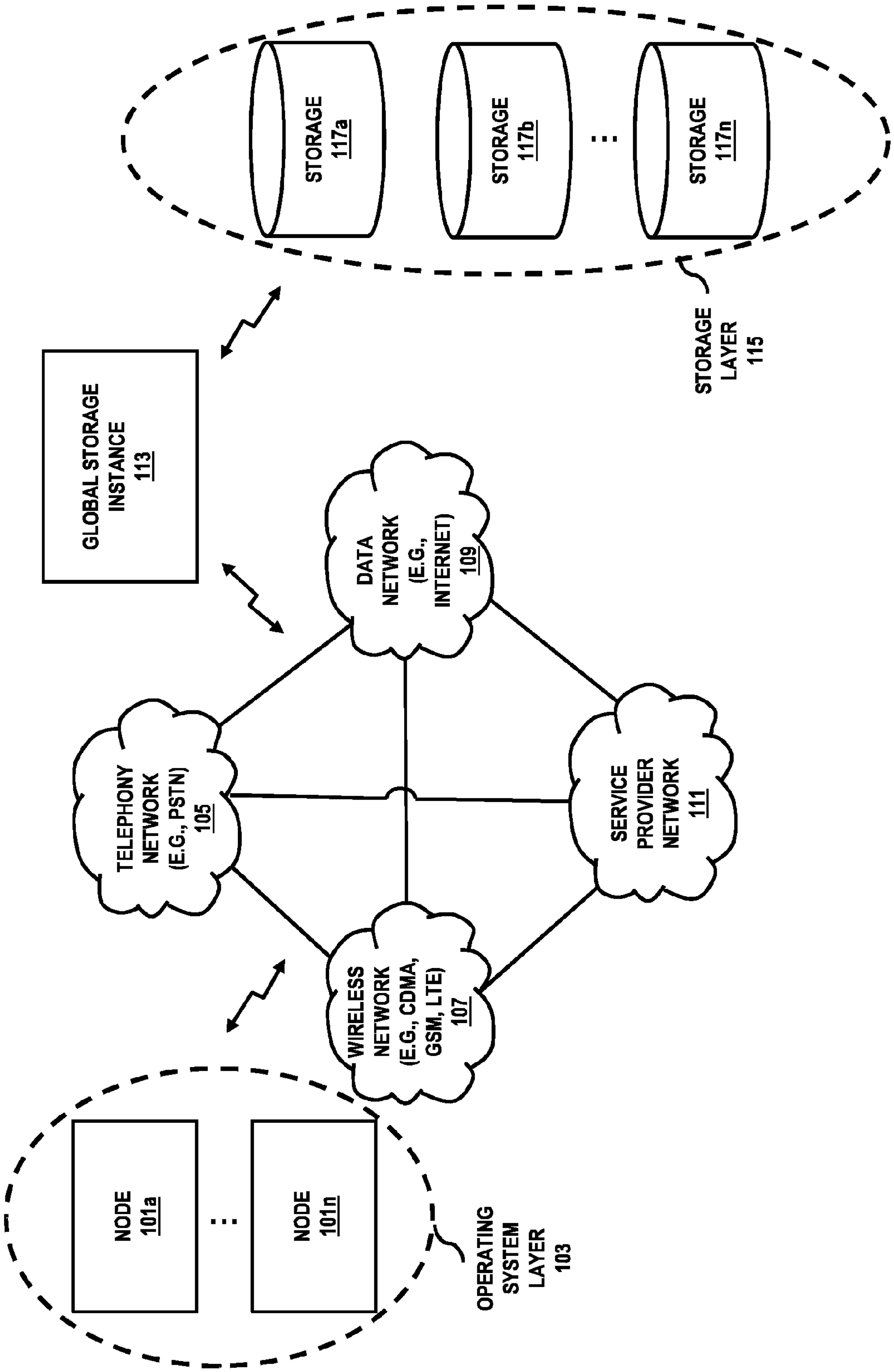
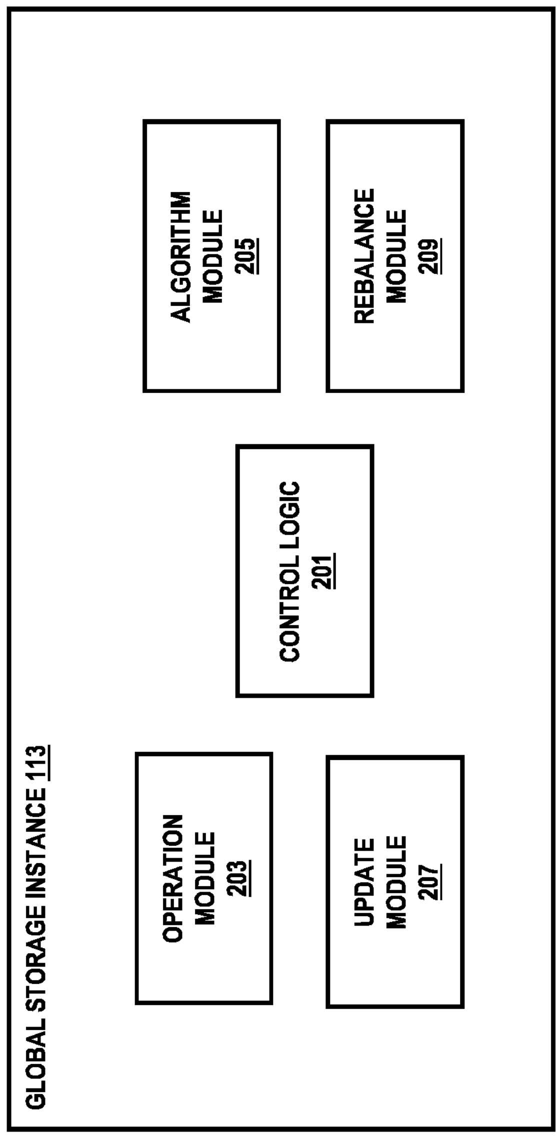


FIG. 1 100


NODE 101a
NODE 101n
OPERATING SYSTEM LAYER 103
TELEPHONY NETWORK (E.G., PSTN) 105
WIRELESS NETWORK (E.G., CDMA, GSM, LTE) 107
DATA NETWORK (E.G., INTERNET) 109
SERVICE PROVIDER NETWORK 111
GLOBAL STORAGE INSTANCE 113
STORAGE 117a
STORAGE 117b
STORAGE 117n
STORAGE LAYER 115


GLOBAL STORAGE INSTANCE 113
OPERATION MODULE 203
UPDATE MODULE 207
CONTROL LOGIC 201
ALGORITHM MODULE 205
REBALANCE MODULE 209

200

FIG. 2A

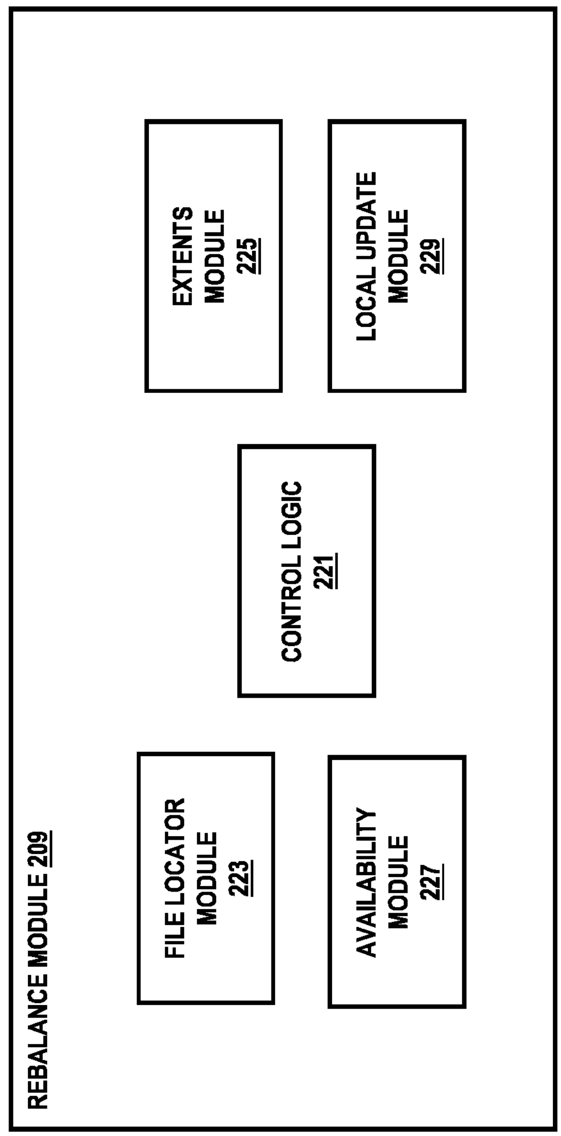

REBALANCE MODULE 209
FILE LOCATOR MODULE 223
AVAILABILITY MODULE 227
CONTROL LOGIC 221
EXTENTS MODULE 225
LOCAL UPDATE MODULE 229

FIG. 2B 220

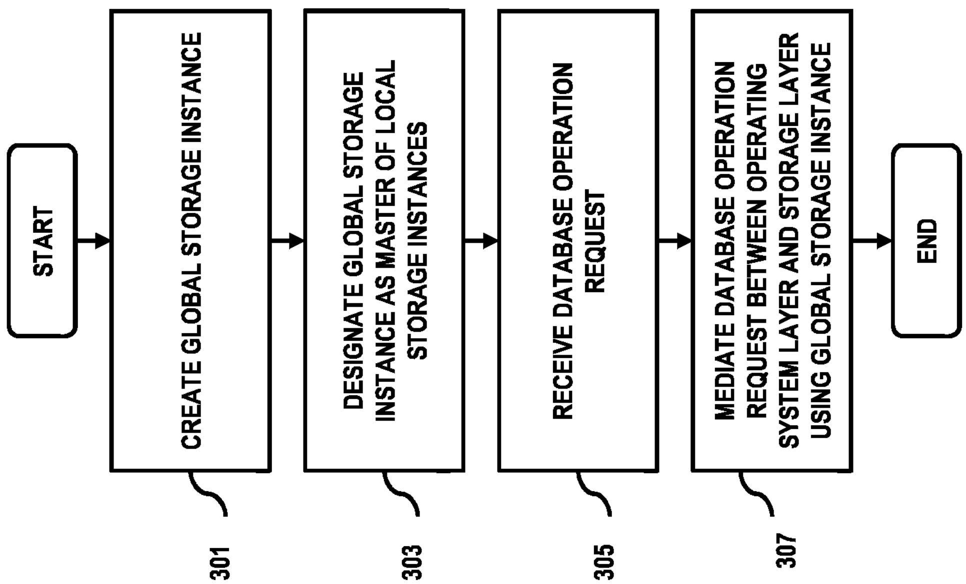

START
CREATE GLOBAL STORAGE INSTANCE
301
DESIGNATE GLOBAL STORAGE INSTANCE AS MASTER OF LOCAL STORAGE INSTANCES
303
RECEIVE DATABASE OPERATION REQUEST
305
MEDIATE DATABASE OPERATION REQUEST BETWEEN OPERATING SYSTEM LAYER AND STORAGE LAYER USING GLOBAL STORAGE INSTANCE
307
END

FIG. 3A 300

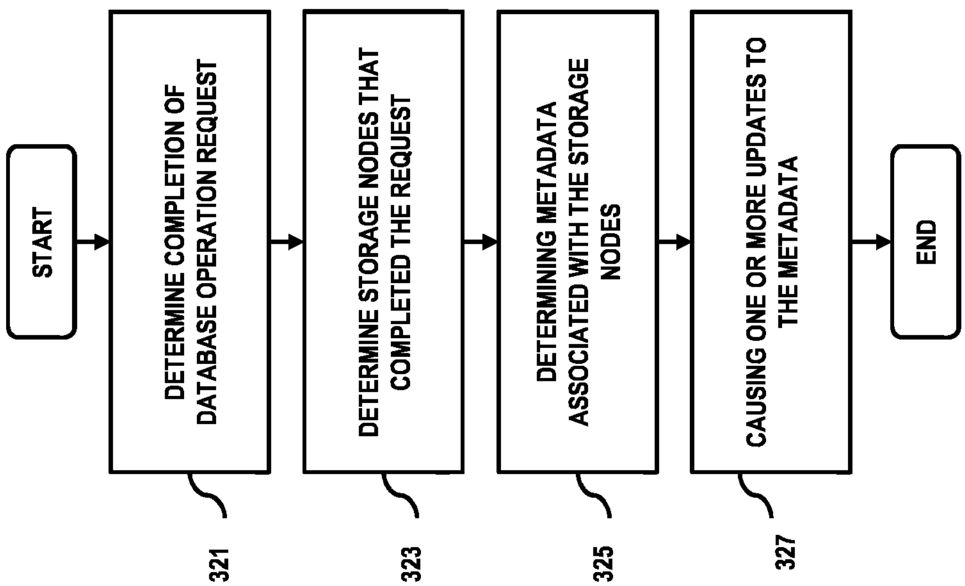

START
DETERMINE COMPLETION OF DATABASE OPERATION REQUEST
DETERMINE STORAGE NODES THAT COMPLETED THE REQUEST
DETERMINING METADATA ASSOCIATED WITH THE STORAGE NODES
CAUSING ONE OR MORE UPDATES TO THE METADATA
END
321
323
325
327

FIG. 3B

320

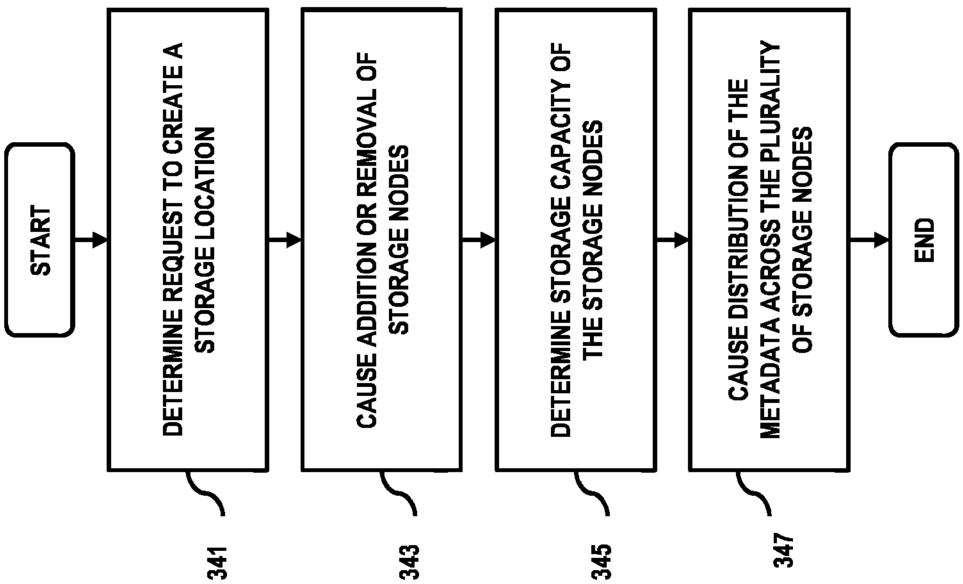
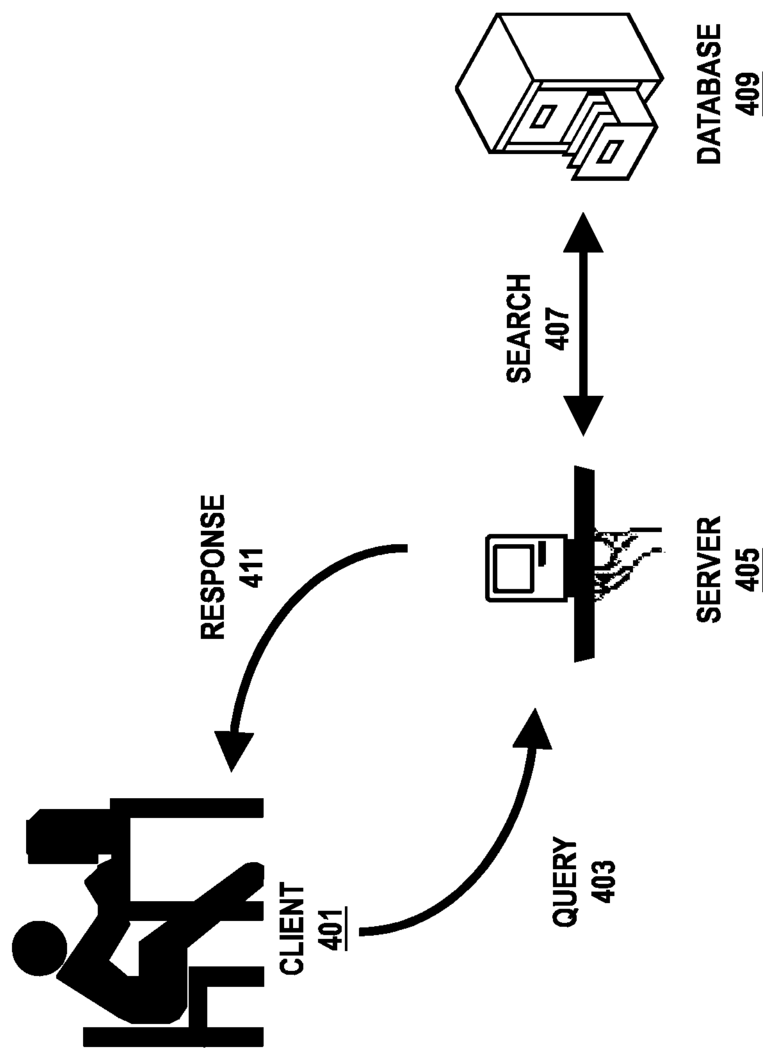

START
DETERMINE REQUEST TO CREATE A STORAGE LOCATION
341
CAUSE ADDITION OR REMOVAL OF STORAGE NODES
343
DETERMINE STORAGE CAPACITY OF THE STORAGE NODES
345
CAUSE DISTRIBUTION OF THE METADATA ACROSS THE PLURALITY OF STORAGE NODES
347
END

FIG. 3C

340

FIG. 4

400



CLIENT
401
QUERY
403
SERVER
405
SEARCH
407
DATABASE
409
RESPONSE
411

FIG. 5

500

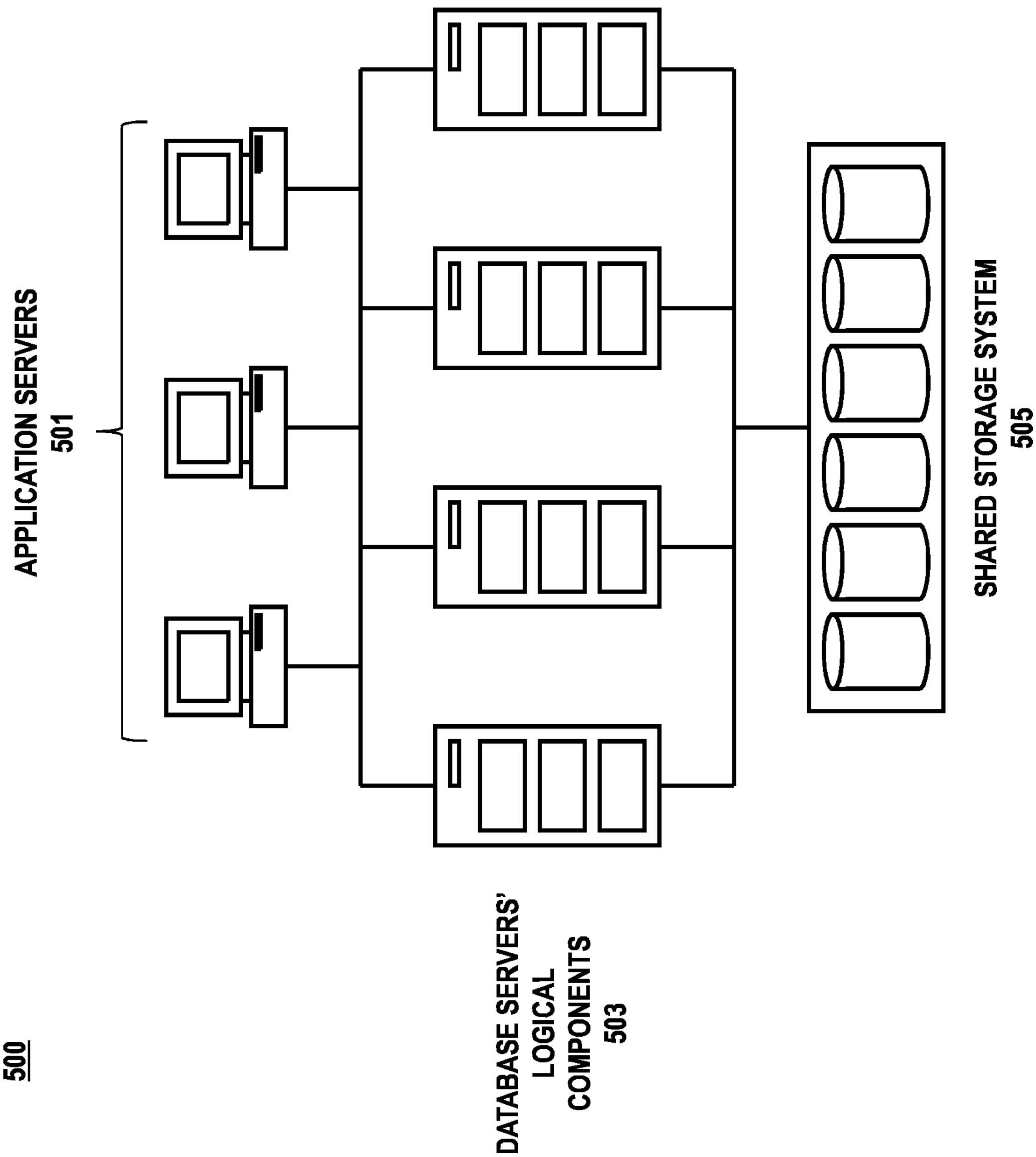
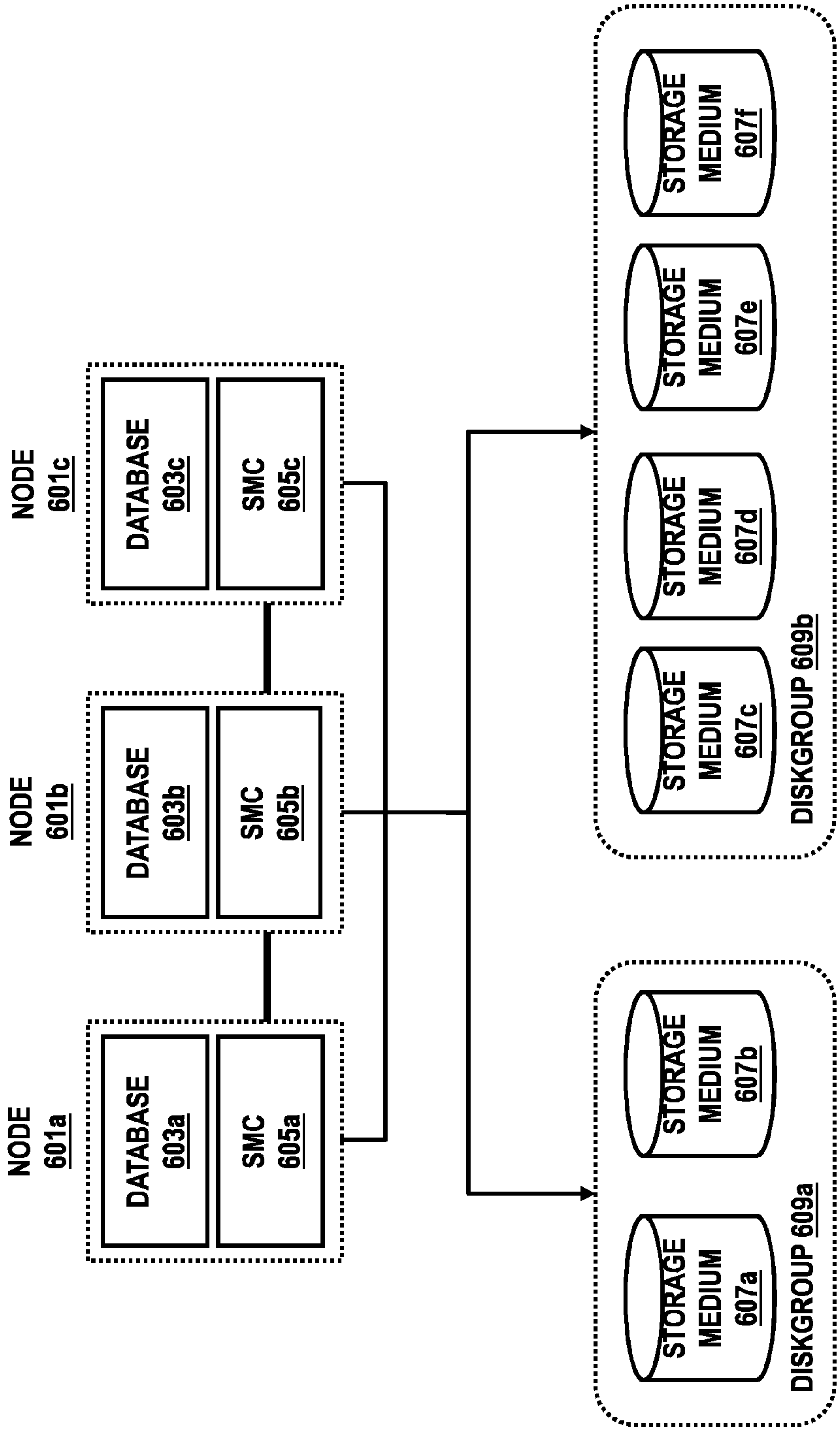

APPLICATION SERVERS
501
DATABASE SERVERS' LOGICAL COMPONENTS
503
SHARED STORAGE SYSTEM
505

FIG. 6A

600


NODE 601a
DATABASE 603a
SMC 605a
NODE 601b
DATABASE 603b
SMC 605b
NODE 601c
DATABASE 603c
SMC 605c
STORAGE MEDIUM 607a
STORAGE MEDIUM 607b
DISKGROUP 609a
STORAGE MEDIUM 607c
STORAGE MEDIUM 607d
STORAGE MEDIUM 607e
STORAGE MEDIUM 607f
DISKGROUP 609b

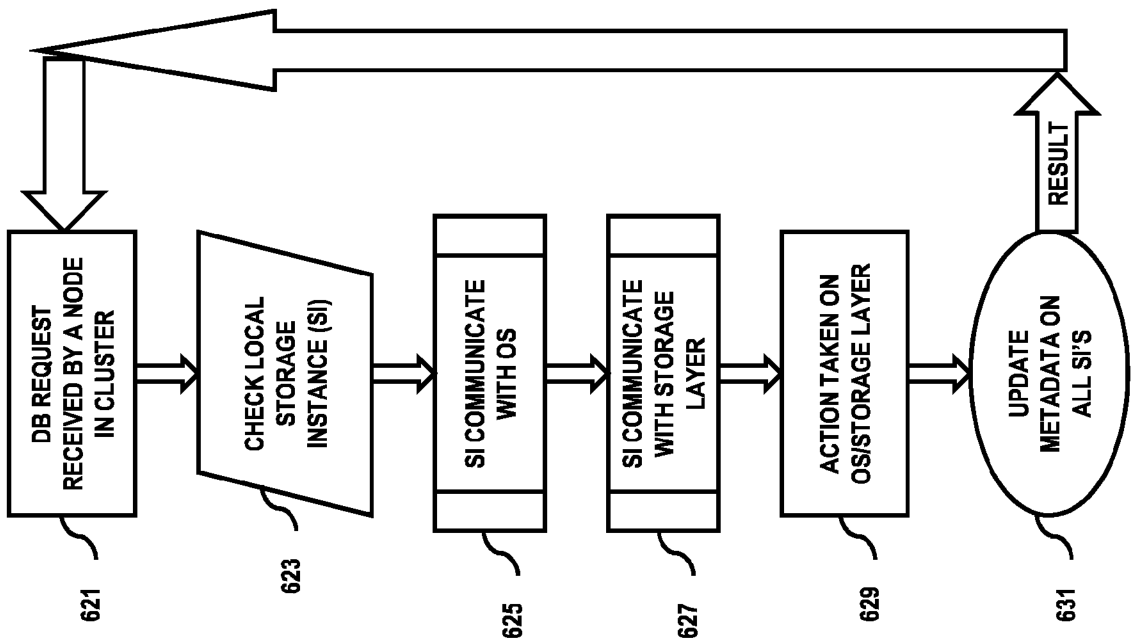
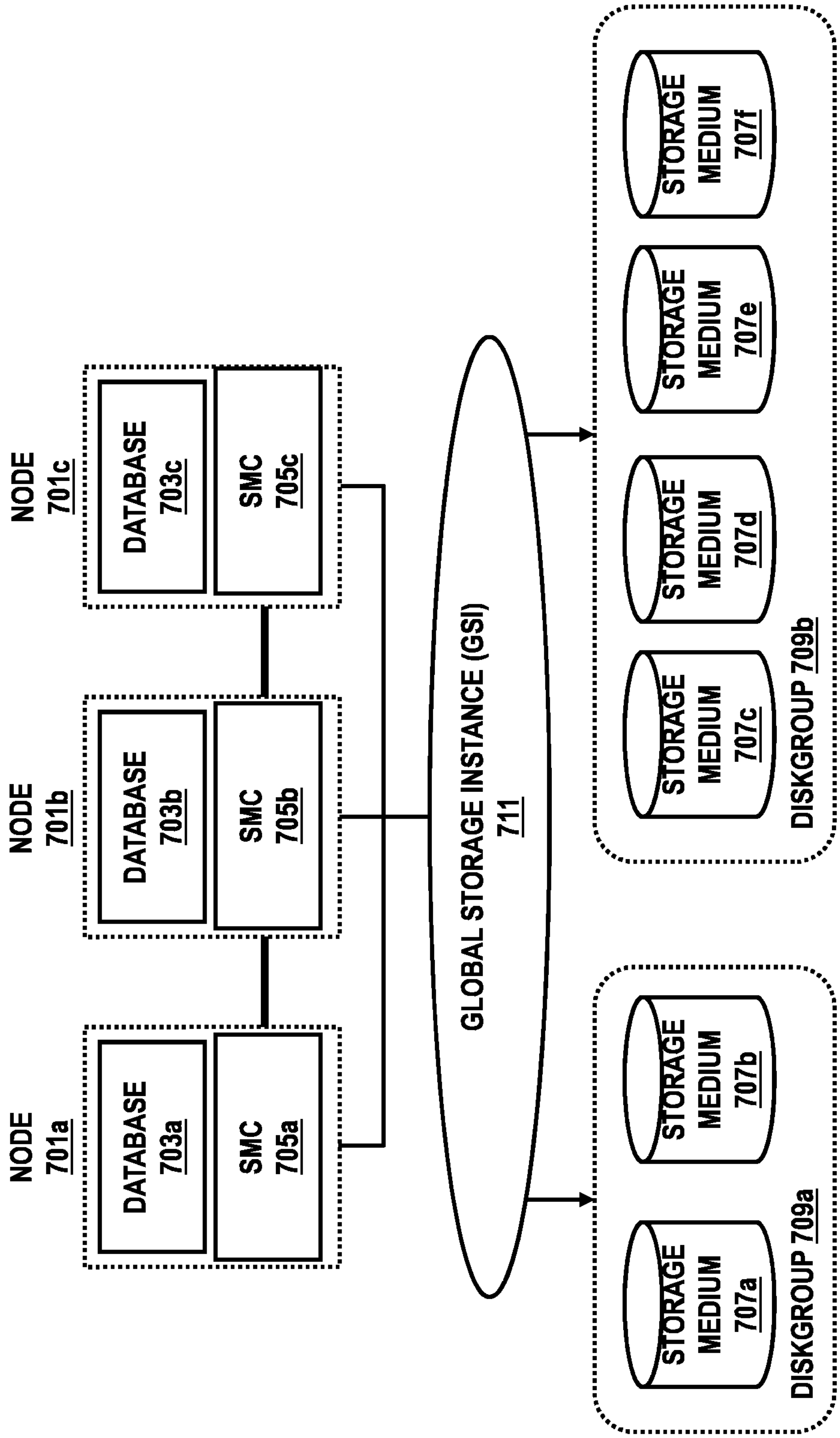
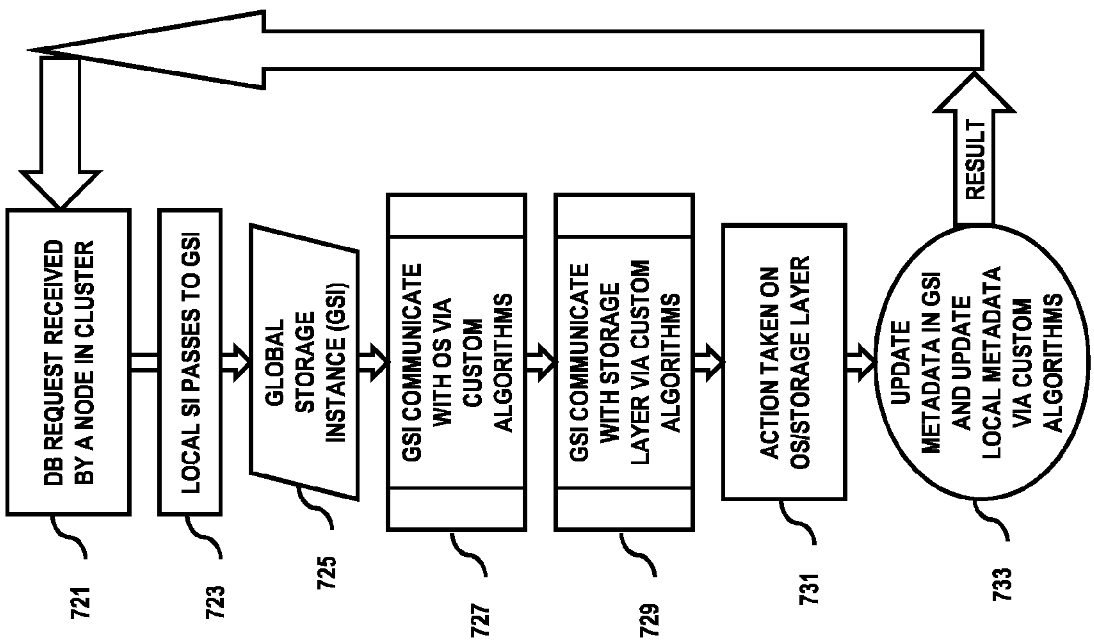

DB REQUEST RECEIVED BY A NODE IN CLUSTER
621
CHECK LOCAL STORAGE INSTANCE (SI)
623
SI COMMUNICATE WITH OS
625
SI COMMUNICATE WITH STORAGE LAYER
627
ACTION TAKEN ON OS/STORAGE LAYER
629
UPDATE METADATA ON ALL SI'S
631
RESULT

FIG. 6B 620

FIG. 7A

700


NODE 701a
DATABASE 703a
SMC 705a
NODE 701b
DATABASE 703b
SMC 705b
NODE 701c
DATABASE 703c
SMC 705c
GLOBAL STORAGE INSTANCE (GSI) 711
STORAGE MEDIUM 707a
STORAGE MEDIUM 707b
DISKGROUP 709a
STORAGE MEDIUM 707c
STORAGE MEDIUM 707d
STORAGE MEDIUM 707e
STORAGE MEDIUM 707f
DISKGROUP 709b



DB REQUEST RECEIVED BY A NODE IN CLUSTER
721
LOCAL SI PASSES TO GSI
723
GLOBAL STORAGE INSTANCE (GSI)
725
GSI COMMUNICATE WITH OS VIA CUSTOM ALGORITHMS
727
GSI COMMUNICATE WITH STORAGE LAYER VIA CUSTOM ALGORITHMS
729
ACTION TAKEN ON OS/STORAGE LAYER
731
UPDATE METADATA IN GSI AND UPDATE LOCAL METADATA VIA CUSTOM ALGORITHMS
733
RESULT

FIG. 7B 720

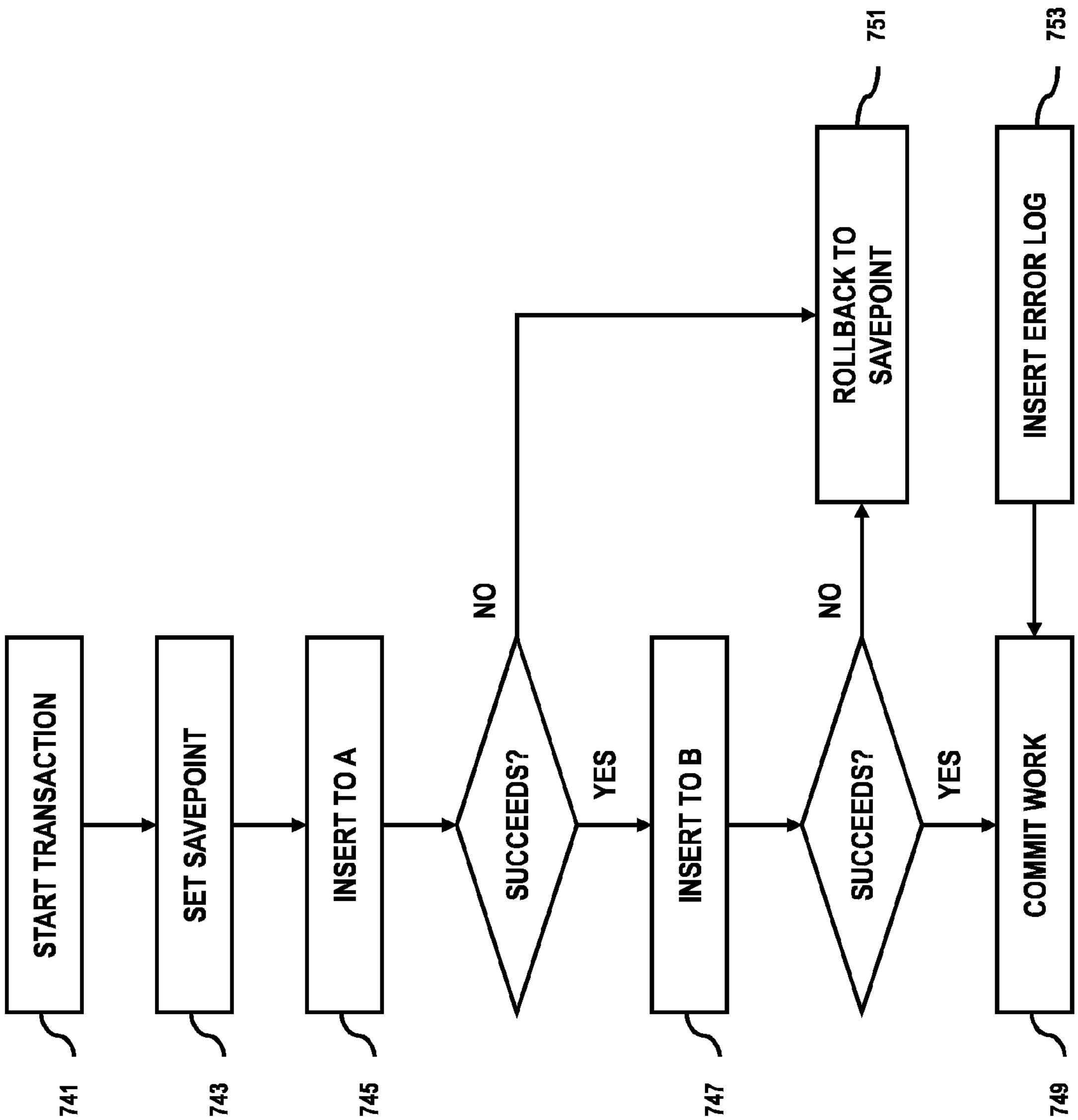
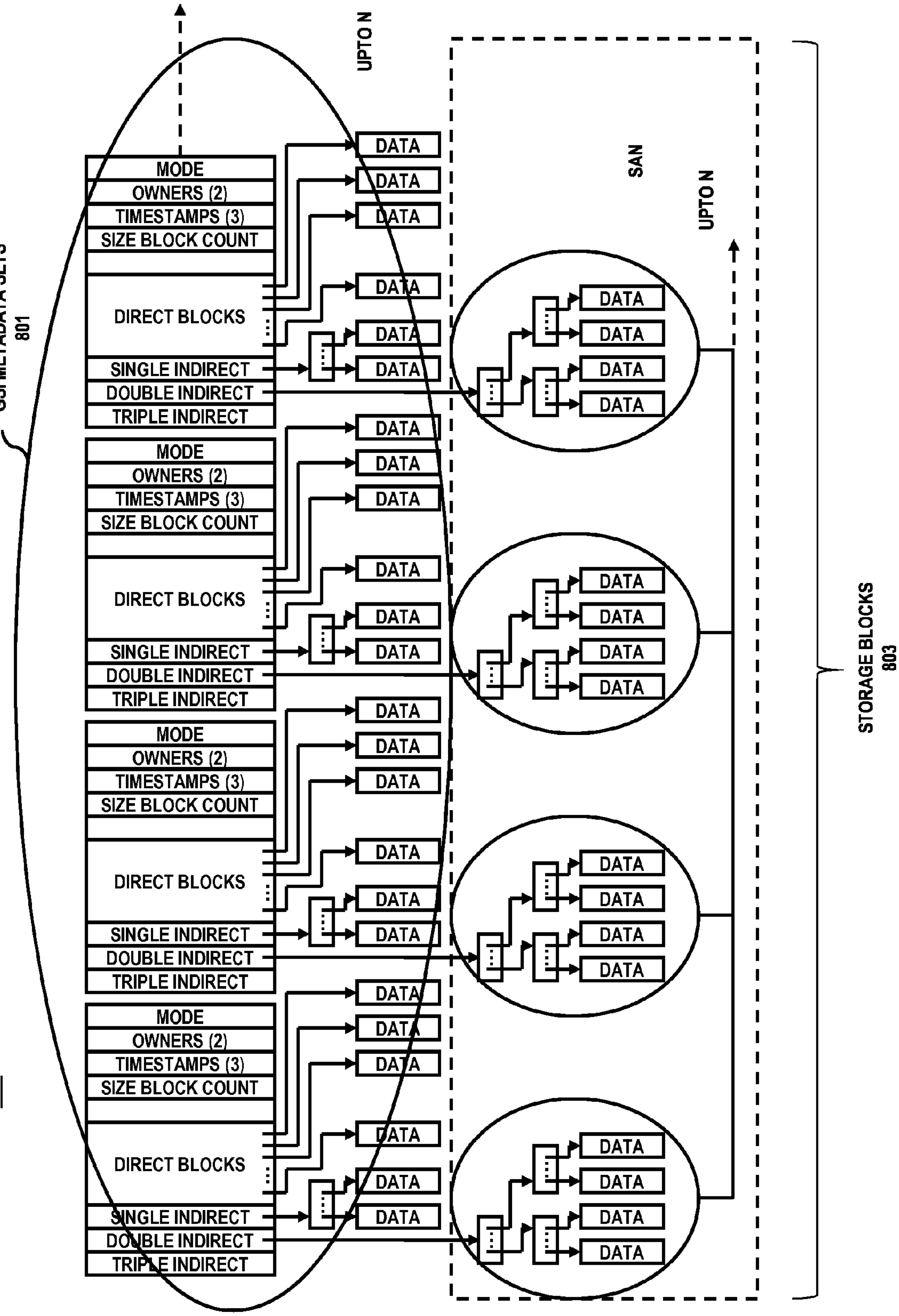

START TRANSACTION
741
SET SAVEPOINT
743
INSERT TO A
745
SUCCEEDS?
YES
NO
INSERT TO B
747
SUCCEEDS?
YES
NO
COMMIT WORK
749
ROLLBACK TO SAVEPOINT
751
INSERT ERROR LOG
753

FIG. 7C 740

FIG. 8A 800


GSI METADATA SETS
801
MODE
OWNERS (2)
TIMESTAMPS (3)
SIZE BLOCK COUNT
DIRECT BLOCKS
SINGLE INDIRECT
DOUBLE INDIRECT
TRIPLE INDIRECT
DATA
UPTO N
SAN
STORAGE BLOCKS
803

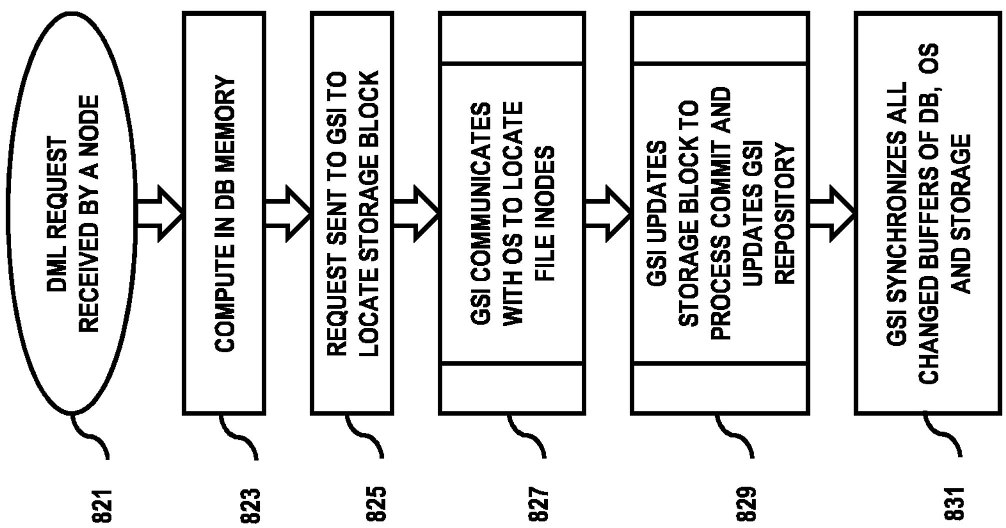

DML REQUEST RECEIVED BY A NODE
COMPUTE IN DB MEMORY
REQUEST SENT TO GSI TO LOCATE STORAGE BLOCK
GSI COMMUNICATES WITH OS TO LOCATE FILE INODES
GSI UPDATES STORAGE BLOCK TO PROCESS COMMIT AND UPDATES GSI REPOSITORY
GSI SYNCHRONIZES ALL CHANGED BUFFERS OF DB, OS AND STORAGE
821
823
825
827
829
831

FIG. 8B 820

FIG. 9A 900

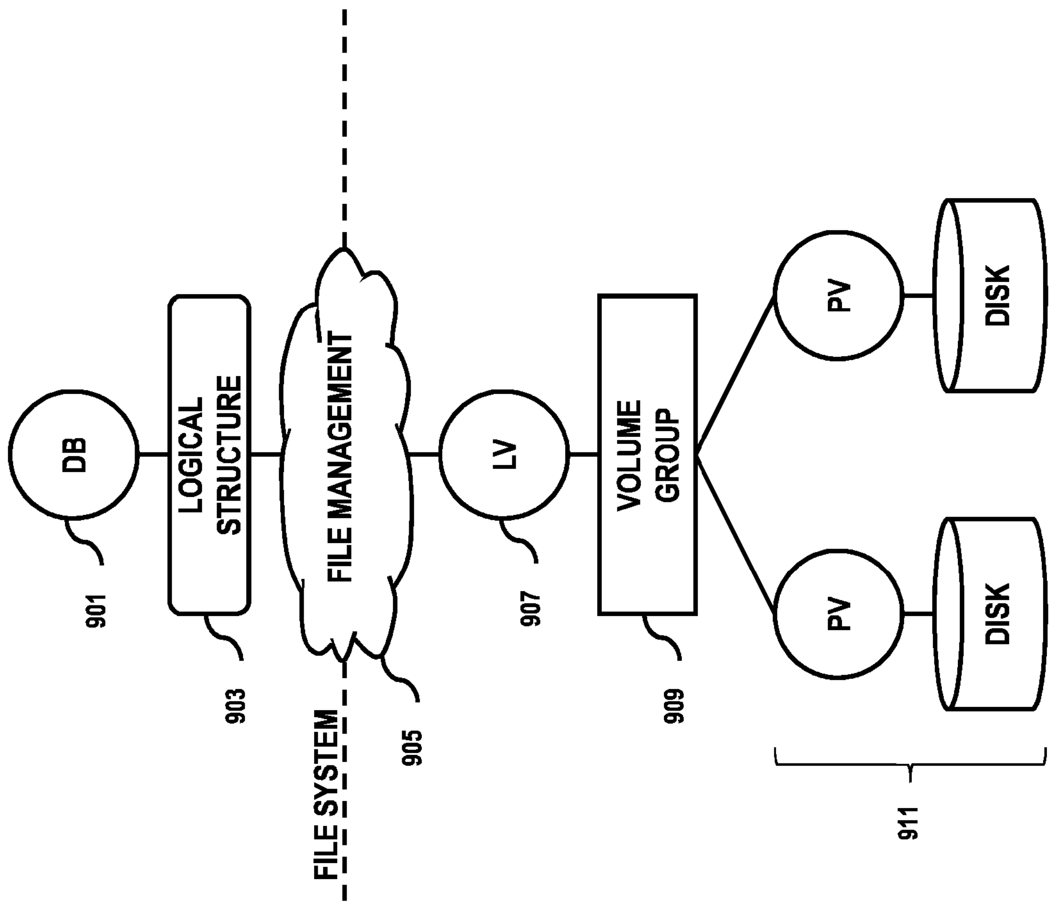

DB
901
LOGICAL STRUCTURE
903
FILE MANAGEMENT
905
FILE SYSTEM
LV
907
VOLUME GROUP
909
PV
PV
DISK
DISK
911

FIG. 9B 920

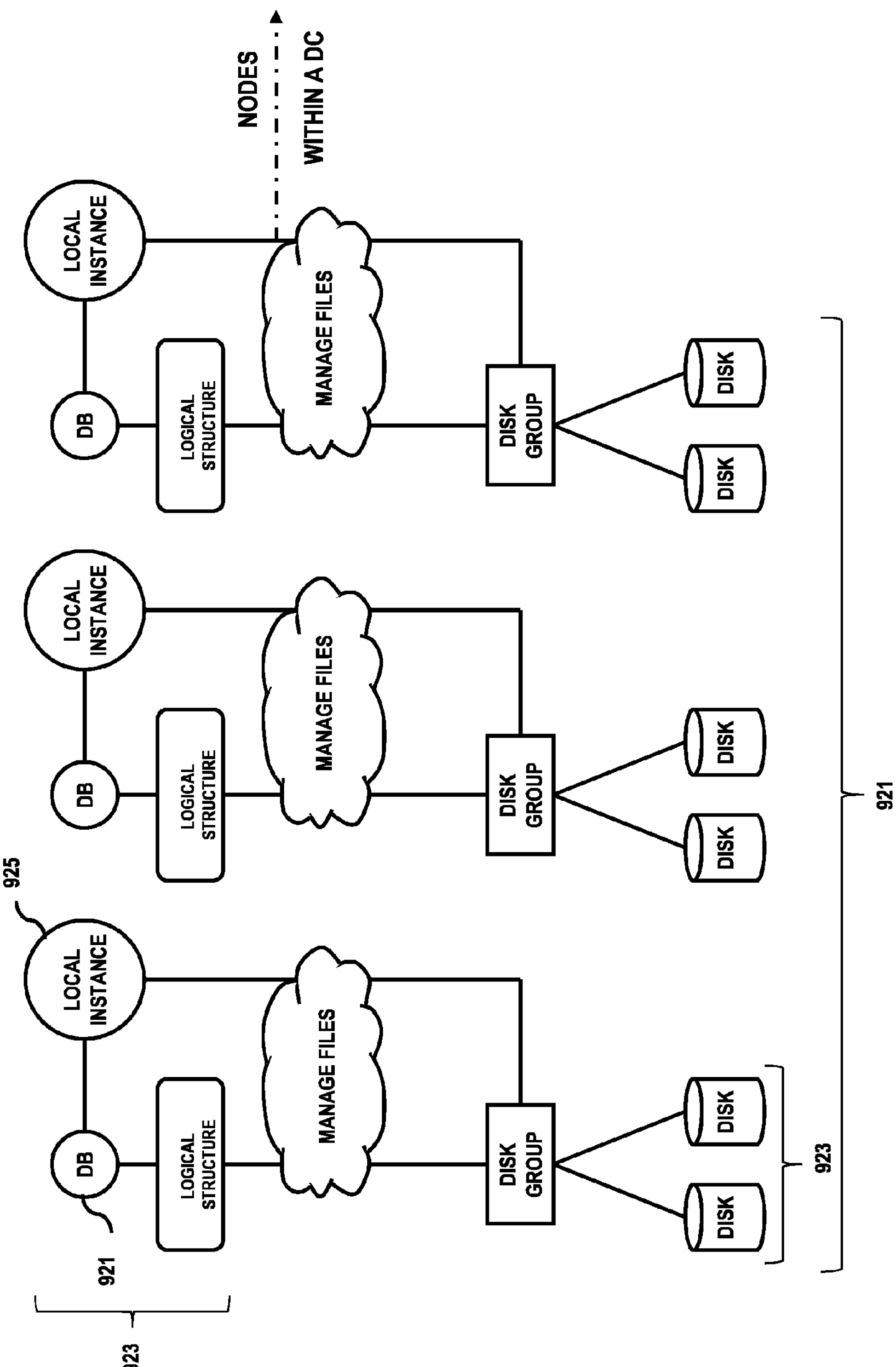

NODES WITHIN A DC
LOCAL INSTANCE
DB
LOGICAL STRUCTURE
MANAGE FILES
DISK GROUP
DISK
DISK
LOCAL INSTANCE
DB
LOGICAL STRUCTURE
MANAGE FILES
DISK GROUP
DISK
DISK
925
LOCAL INSTANCE
DB
LOGICAL STRUCTURE
MANAGE FILES
DISK GROUP
DISK
DISK
921
923
923
921

FIG. 9C 940

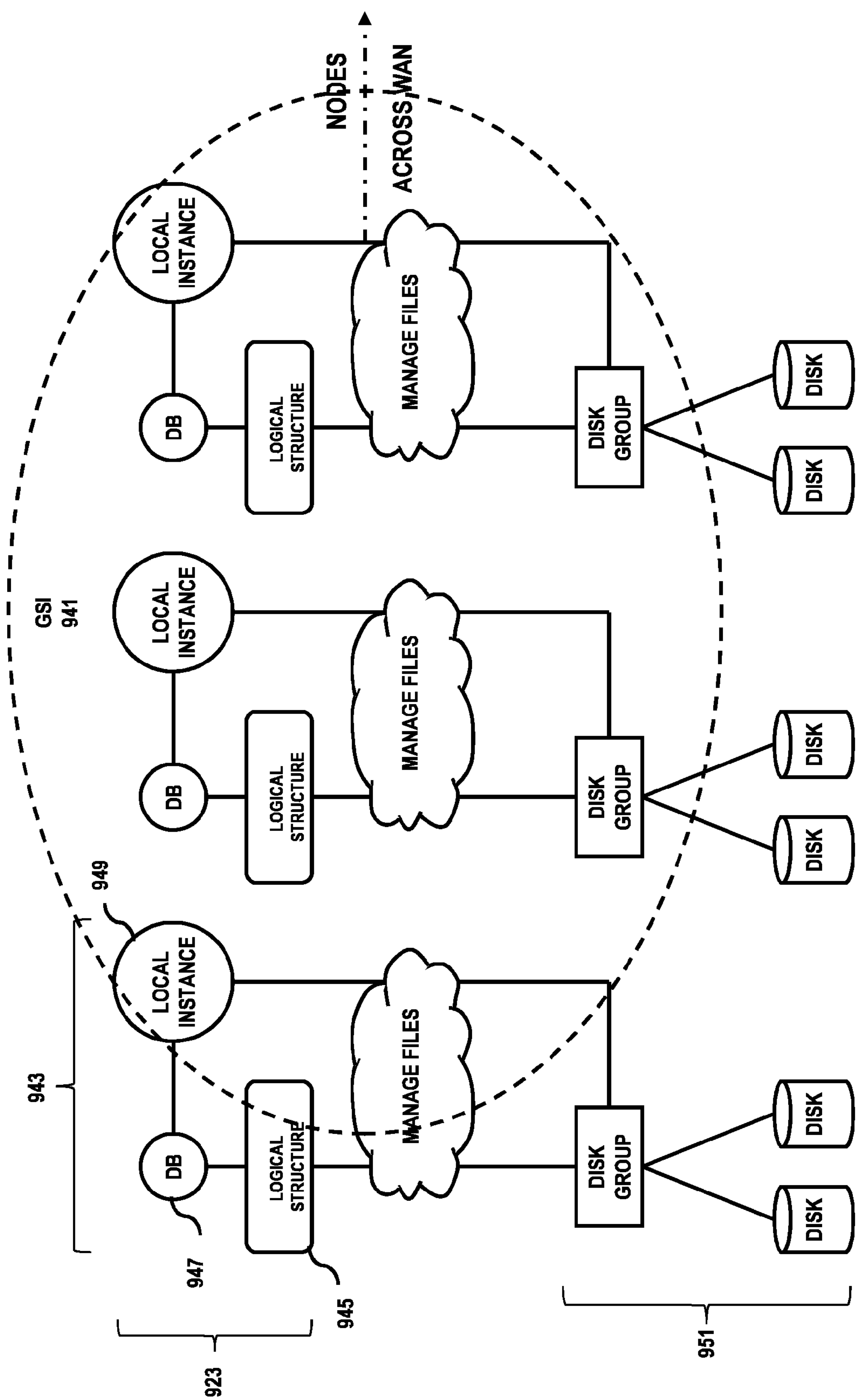
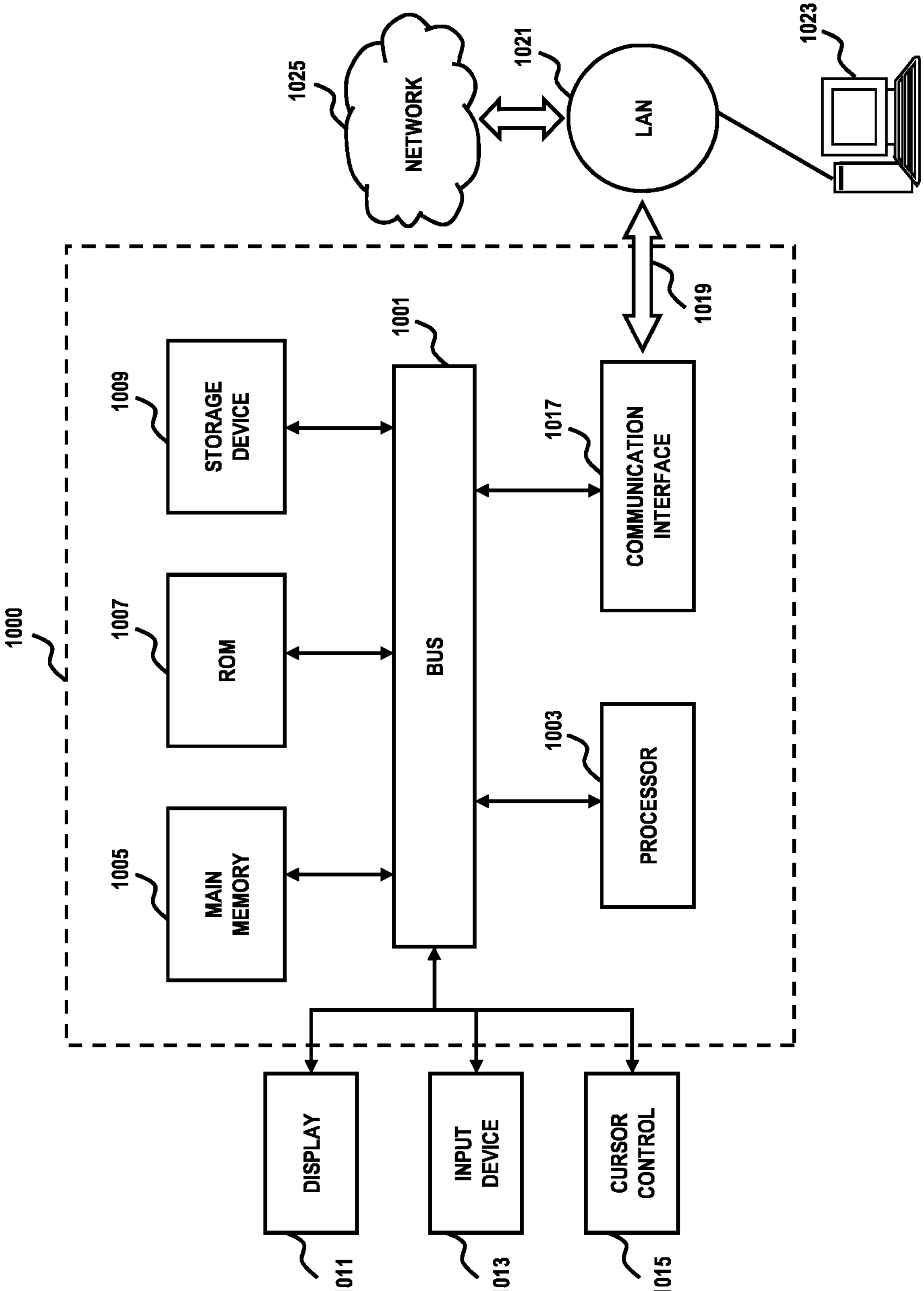
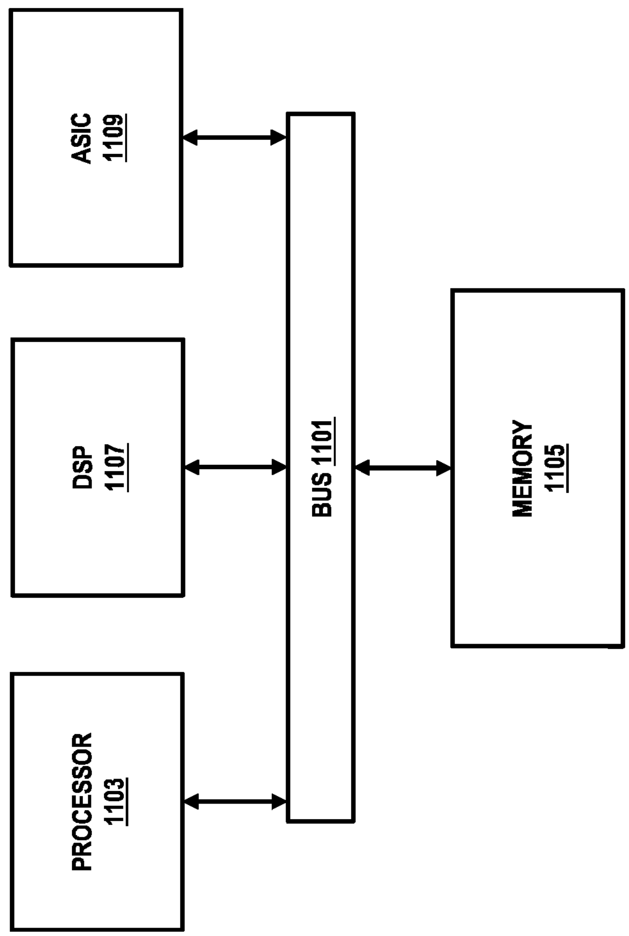

NODES
ACROSS WAN
GSI
941
LOCAL INSTANCE
DB
LOGICAL STRUCTURE
MANAGE FILES
DISK GROUP
DISK
949
943
947
945
923
951

FIG. 10 1000



1000
1005
MAIN MEMORY
1007
ROM
1009
STORAGE DEVICE
1001
BUS
1003
PROCESSOR
1017
COMMUNICATION INTERFACE
1019
1025
NETWORK
1021
LAN
1023
DISPLAY
1011
INPUT DEVICE
1013
CURSOR CONTROL
1015



1100

FIG. 11

METHOD AND SYSTEM FOR UNIFIED TECHNOLOGICAL STACK MANAGEMENT FOR RELATIONAL DATABASES

BACKGROUND INFORMATION

Service providers are continually challenged to deliver value and convenience to consumers by, for example, providing compelling network services. One area of development has been expanding communication between relational databases. For example, operating files and metadata are managed locally at data centers and nodes within data centers. Nodes in the same vicinity may be connected for the nodes to coordinate. Data center communication takes place at clusters of database nodes within data centers or, at best, geographically neighboring data centers. Storage modules with data centers cannot communicate across vast geographic regions and data centers. As such, service providers face challenges in scaling operations beyond individual data centers and storing data across data centers where the nodes are not in close proximity.

Based on the foregoing, there is a need for providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes within data centers.

BRIEF DESCRIPTION OF THE DRAWINGS

Various exemplary embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

FIG. **1** is a diagram of a system capable of providing unified technological stack management (e.g., a global storage instance) where metadata is delocalized from storage nodes, according to an exemplary embodiment;

FIG. **2**A is a diagram of a global storage instance capable of providing a global repository where metadata is delocalized from storage nodes, according to an exemplary embodiment;

FIG. **2**B is a diagram of a rebalance module capable of allocating storage space for a cluster of nodes, according to an exemplary embodiment;

FIG. **3**A is a flowchart of providing unified technological stack management (e.g., a global storage instance) where metadata is delocalized from storage nodes, according to an exemplary embodiment;

FIG. **3**B is a flowchart of mediating the database operation request between the operating system layer and the storage layer using the global storage instance, according to an exemplary embodiment;

FIG. **3**C is a flowchart of rebalancing storage nodes, according to an exemplary embodiment;

FIG. **4** is a model showing the traditional, client server model for RDBMS architecture, according to an exemplary embodiment;

FIG. **5** is a model where logical or memory components of a database are split from application servers, according to an exemplary embodiment;

FIG. **6**A is a model showing storage instance clustering, according to an exemplary embodiment;

FIG. **6**B is a flowchart of a communication amongst the layers in model **600**, according to an exemplary embodiment;

FIG. **7**A is a model showing use of a global storage instance (GSI), according to an exemplary embodiment;

FIG. **7**B is a flowchart of a communication amongst the layers in model **700**, according to an exemplary embodiment;

FIG. **7**C is a flowchart of a communication amongst the layers in model **700** that leads to creation of a storage location, according to an exemplary embodiment;

FIG. **8**A is a diagram of a global storage instance as a centralized form of managing a technology stack, according to an exemplary embodiment;

FIG. **8**B is a flowchart of a GSI operating as a master instance, with local SIs as slave instances to the GSI, according to an exemplary embodiment;

FIG. **9**A is a flowchart of a storage management operation that takes place in conjunction with the synchronization and updating discussed above, according to an exemplary embodiment;

FIG. **9**B is a diagram of multi-instance management (e.g., model **600**), according to an exemplary embodiment;

FIG. **9**C is a diagram **940** showing use of global instance storage management (e.g., model **700**), according to an exemplary embodiment;

FIG. **10** is a diagram of a computer system that can be used to implement various exemplary embodiments; and

FIG. **11** is a diagram of a chip set that can be used to implement various exemplary embodiments.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An apparatus, method, and software for providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes, is described. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It is apparent, however, to one skilled in the art that the present invention may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the preferred embodiments of the invention.

Although the various exemplary embodiments are described with respect to processing cloud computing and services, it is contemplated that these embodiments have applicability to other computing technologies and architectures.

FIG. **1** is a diagram of a system **100** for providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes, according to one embodiment. For the purpose of illustration, system **100** for providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes, for example, nodes **101**_a_-**101**_n_ (or nodes **101**). In one embodiment, nodes **101** may comprise an operating system layer **103**. Nodes **101** may comprise user devices, data centers, databases, or any entity that may support an operating system. According to certain embodiments, nodes **101** may communicate over one or more networks, such as telephony network **105**, wireless network **107**, data network **109**, and/or service provider network **111**. In one embodiment, the nodes **101** communicate over the networks with each other, as well as a global storage instance **113** and storage layer **115**. Storage layer **115** may comprise multiple storage components, for instance, storage **117**_a_, **117**_b_-**117**_n_ (or storage **117**). In some embodiments, the storage layer **115** may contain several storage components, grouped in different sets. While specific reference will be made hereto, it is contemplated that system **100** may embody many forms and include multiple and/or alternative components and facilities.

It is observed that scalability of relational database management systems (RDBMS) is constrained by the need for nodes to be in close proximity to each other in order to coordinate amongst one another. The need for geographical proximity for interaction limits the ability of RDBMS to act across geographic areas and manage resources (e.g., distribute storage across data centers). Traditionally, RDBMS rely on a client server model. In this model, a client or end user initiates a transaction represented by a SQL (Structured Query Language) query. The query is then passed to a database that would process the query, retrieve the results set, and pass it back to the user. To prevent the entire transaction from shutting down if the case of any database failure, logical or memory components of the database were split out from the database. This way, the logical or the memory components could run on multiple servers so that even if machines were down, remaining nodes could carry out the transaction and the end user would not be impacted. However, this model was limited by requiring the servers to be in a single data center, connected via a shared storage. Requiring servers to be in a single data center translates into space constraints since it may be hard to sustain multiple databases within a single data center, especially given the growth in size of databases. Connecting only servers within a single data center also means that resources available at distant data centers may not be leveraged for use.

To overcome this limitation, the next development was to capture operating system (OS)-related metadata within a storage instance (SI) and conduct communication between nodes, OS, and storage, with the metadata in the SI. In this embodiment, the SI lives on each node in a database cluster. When the SI receives a request, it may check with an OS kernel and storage layer, then take action based on the request. After the action from the request is completed, the metadata across the cluster nodes and SIs are updated and the SIs are synchronized to account for the action. However, the metadata that permits execution of the action and communication amongst the nodes, OS, and storage layer, are still local and contained within each data center. The OS files and metadata are managed locally by each node in the cluster, meaning that nodes must be proximate each other and connected by high speed interconnects to coordinate the information among them. The requirement for physical proximity limits the scalability of RDBMS systems using this model.

Therefore, the approach of system **100**, according to certain exemplary embodiments, stems from the recognition that further scalability of RDBMS hinges on separating metadata from their local nodes. The system **100** proposes creating a global repository that can manage the metadata of all the nodes in a database cluster. In one embodiment, the global repository may be known as a global storage instance (GSI) **113**, where the GSI **113** acts as a repository that contains the metadata of all the nodes of a database cluster in a centralized location. In one embodiment, the metadata may include metadata that permits information about a file system object needed to respond to end user requests. For example, the GSI **113** may provide metadata needed to locate nodes and file content relevant to executing a user transaction. The metadata may include storage extents of records and/or database pointers. Such metadata may be used to retrieve the actual file content from nodes to complete the transaction. In keeping the metadata in a GSI **113**, metadata is delocalized from nodes **101** so that metadata management takes place across the operating system layer, rather than at individual nodes **101**. This way, nodes no longer have to be geographically close to one another to communicate. This way, storage in system **100** may also be remote. With localized management, metadata is local to each node, so storage much also be proximate the node. Since metadata is decoupled from nodes while employing a GSI **113**, storage can be in a different location from nodes and still have the metadata to retrieve file content. Then, system **100** also allows for storage **117** to be added to the storage layer **115** or storage in geographically different locations from nodes **101** to be employed by nodes **101**. The need for storage **117** to be proximate nodes **101** is not necessary since metadata to request file content from storage **117** is centralized the GSI **113**.

After completing a user transaction, metadata may be updated to reflect the completion. In this way, the GSI **113** may act as an intermediary between the operating system layer **103** and the storage layer **115**. For example, the GSI **113** may receive a request for a logical structure command related to a database operation. Then, the GSI **113** may check the storage layer **115** for storage extents related to the operation. In one embodiment, the GSI **113** may further perform the logical structure command at the storage layer **115**. Upon completion of the command and operation, the GSI may account for the storage space available in system **100** (e.g., at nodes **101**) and rebalance metadata and storage across all the nodes.

In a further embodiment, the GSI **113** may act in a master-slave configuration with local storage instances. For example, each node **101**a-**101**n may house a local storage instance with metadata contained only within the respective node **101**a-**101**n. In other words, the local storage instance may house local metadata. In some embodiments, the GSI **113** may check local storage instances for file location information and check the storage layer **115** for storage extents in response to a request. In one embodiment, user transaction requests (e.g., database operation requests) may be evaluated, first, by local storage instances before they are passed to GSI **113**. For example, a GSI **113** may communicate with the local storage instances and operating system layer **103** via custom algorithms. In these cases, local storage instances may also pass local metadata for file location to GSI **113** along with the request. After operation completion, the GSI **113** may take the additional step of updating local metadata at the local storage instances, based on the operation involved with the request. In one scenario, the GSI **113** may also communicate with the storage layer **115** via custom algorithms to act as the intermediary between local storage instances at nodes **101** and the storage **117**. Furthermore, the GSI **113** may rely on custom algorithms to update metadata in the GSI **113** and local metadata at local storage instances.

This method of keeping metadata in a global repository overcomes the need for nodes to be geographically proximate one another and storage components. The method also permits metadata management across entire clusters of nodes **101** in the operating system layer **103**. For instance, the GSI **113** may have an overview of the storage space and allocations across an entire cluster of nodes **101** and rebalance metadata at nodes **101** after completion of an operation based on the storage space allocations. Previously, rebalancing was local and/or nodes performing an operation were updated with metadata for completed operations. At best, nodes corresponding the nodes performing the operation were likewise updated or part of the rebalancing. However, only nodes that were proximate one another could be connected to communicate. With a GSI **113**, all the storage space in a cluster may be utilized to store updates after operations are completed.

In one embodiment, the nodes **101** may communicate with users and/or one another. For instance, nodes may include user devices that directly plug into a system. At which case, requests at nodes **101** may comprise user interactions with respective nodes. In another embodiment, nodes **101** may also comprise data centers. Essentially, nodes **101** may comprise any device that may support a database and an operating system. In one embodiment, nodes **101** may freely enter and exit the operating system layer **103** based on user transaction and/or database operation requests. For example, if nodes **101** request access to a particular storage **117**, the GSI **113** may determine the nodes **101** joining the operating system layer **103** and direct the communication between the nodes **101** and the particular storage **117**.

In one embodiment, the operating system layer **103** may comprise a collection of nodes **101**. In one embodiment, the operating system layer **103** may allow for the addition of nodes **101**. For example, the operating system layer **103** may connect to networks **105-111** and GSI **113** to execute user transactions using data objects in the storage layer **115**. In one scenario, any nodes **101** requiring access to data objects in the storage layer **115** may join the operating system layer **103** and thus come to communicate with the GSI **113**, which orchestrates the communication. In one embodiment, the operating system layer **103** may comprise any nodes **101** that use the same operating system. In another embodiment, the operating system layer **103** may include only nodes **101** that actively interface with the storage layer **115**. In one embodiment, the operating system layer **103** may stand for a database cluster, containing all the nodes **101** in such a database cluster. For example, the cluster may exist in a centralized location.

In one embodiment, the GSI **113** may act as a global repository that contains the metadata of all the nodes **101**. For example, the GSI **113** may serve as a centralized location with metadata indicating information about a file system object. In one scenario, such metadata may include file type, device node, file ownership, access information, meaning information referring to where a file's data content may be located within the storage layer **115**. In storing such metadata, the GSI **113** holds metadata such that the GSI **113** may retrieve the file at the storage layer **115** when requests are made at the operating system layer **103**. In one embodiment, the GSI **113** may employ custom algorithms to interface between nodes **101**, operating systems on nodes **101** (from operating system layer **103**), and the storage layer **115**.

The GSI **113** may further rebalance all the nodes **101** within a cluster and/or operating system layer **103**. For example, the GSI **113** may determine a logical structure command from nodes **101** and check for storage extents in the storage layer **115**. In one embodiment, the GSI **113** may further perform the logical structure-related operation (or operation that warranted the logical structure command) at the storage layer **115**. Afterwards, the GSI **113**, may rebalance all the nodes **101** with metadata associated with operation completion. For example, GSI **113** may evaluate distribution and/or availability of storage space on databases at nodes **101** and distribute the most recent metadata from operation completion accordingly.

In one embodiment, the storage layer **115** may contain storage **117**. In one embodiment, the storage layer **115** may manage the storage **117**, meaning storage layer **115** may remove or add storage **117**. In one embodiment, the storage layer **115** may comprise storage **117** in groups. For example, storage **117*a*** may exist independently on storage layer **115** while storage **117*b*-117*n*** may be part of a storage group. The groupings in storage layer **115** may affect execution of custom algorithms at the GSI **113**.

The data network **109** can interact with one or more networks, such as a telephony network **105**, a wireless network **107**, and/or a service provider network **111**. The service provider network **111** can include at least one application provides services to the service provider network **111**. In one embodiment, user transactions or requests for database operations may arrive through the service provider network **111**. Additional services associated with, for example, the telephony network **105**, the wireless network **107**, or the data network **109**, may also interact with the operating system layer **103**, GSI **113**, and storage layer **115**. By way of example, a service associated with the data network **109** can store information to files associated with an application of the service provider network **111**. In one embodiment, the storage layer **115** may communicate through the data network **109**, where applications from the service provider network **111** may collect and store information associated with nodes **101**. Then, the applications in the service provider network **111** may provide for the nodes **101** to receive the stored information from storage layer **115**.

For illustrative purposes, the networks **105-111** may be any suitable wireline and/or wireless network, and be managed by one or more service providers. For example, telephony network **105** may include a circuit-switched network, such as the public switched telephone network (PSTN), an integrated services digital network (ISDN), a private branch exchange (PBX), or other like network. Wireless network **107** may employ various technologies including, for example, code division multiple access (CDMA), enhanced data rates for global evolution (EDGE), general packet radio service (GPRS), mobile ad hoc network (MANET), global system for mobile communications (GSM), Internet protocol multimedia subsystem (IMS), universal mobile telecommunications system (UMTS), etc., as well as any other suitable wireless medium, e.g., microwave access (WiMAX), wireless fidelity (WiFi), satellite, and the like. Meanwhile, data network **109** may be any local area network (LAN), metropolitan area network (MAN), wide area network (WAN), the Internet, or any other suitable packet-switched network, such as a commercially owned, proprietary packet-switched network, such as a proprietary cable or fiber-optic network.

Although depicted as separate entities, networks **105-111** may be completely or partially contained within one another, or may embody one or more of the aforementioned infrastructures. For instance, the service provider network **111** may embody circuit-switched and/or packet-switched networks that include facilities to provide for transport of circuit-switched and/or packet-based communications. It is further contemplated that networks **105-111** may include components and facilities to provide for signaling and/or bearer communications between the various components or facilities of system **100**. In this manner, networks **105-111** may embody or include portions of a signaling system 7 (SS7) network, or other suitable infrastructure to support control and signaling functions.

According to exemplary embodiments, end user devices may be utilized to communicate over system **100** and may include any customer premise equipment (CPE) capable of sending and/or receiving information over one or more of networks **105-111**. (Nodes **101** may include end user devices.) For instance, voice terminal may be any suitable plain old telephone service (POTS) device, facsimile machine, etc., whereas mobile device (or terminal) may be any cellular phone, radiophone, satellite phone, smart phone, wireless phone, or any other suitable mobile device, such as a personal digital assistant (PDA), pocket personal computer, tablet, customized hardware, etc.

FIG. **2**A is a diagram **200** of a global storage instance capable of providing a global repository where metadata is delocalized from storage nodes, according to one embodiment. GSI **113** may comprise computing hardware (such as described with respect to FIG. **11**), as well as include one or more components configured to execute the processes described herein for providing the processing services of system **100**. In one implementation, the GSI **113** contains control logic **201** an operation module **203**, an algorithm module **205**, an update module **207**, and a rebalance module **209**. The control logic **201** performs control logic functions and facilitates coordination among the other components of GSI **113**.

In one embodiment, the control logic **201** and operation module **203** may receive a database operation request from an operating system layer. For instance, the operation system layer may include the operating system layer **103** with nodes **101**. As previously discussed, the nodes **101** may receive requests for transactions from users and/or other nodes. In one embodiment, the control logic **201** and operation module **203** may create a global storage instance by communicating with a plurality of storage nodes out of the nodes **101** and determining metadata associated with the plurality of storage nodes. For example, the control logic **201** and operation module **203** may determine a plurality of storage nodes and determine metadata associated with the plurality of storage nodes. Then, the control logic **201** and operation module **203** may set up a global storage instance such that the global storage instance contains the metadata for a storage layer where the plurality of storage nodes reside. In one embodiment, the global storage instance may be delocalized from the plurality of storage nodes so that metadata within the global storage instance may not be specific to a particular node **101***a*. For instance, the control logic **201** and operation module **203** may manage metadata within the GSI **113** such that the GSI **113** may contain metadata associated with multiple nodes **101***a*-**101***k*.

In a further embodiment, the control logic **201** and operation module **203** may receive a database operation request from an operating system layer, where the request arrives from a local storage instance. For example, the GSI **113** may operate in a master-slave model with local storage instances at each node **101**. In such a case, the GSI **113** may determine the nodes **101** and associated local storage instances with which it may communicate in order to determine requests from the local storage instances and locate other local storage instances that may aid in responding to the requests. Furthermore, the GSI **113** may communicate with the local storage instances to update its metadata after completion of the requested database operation.

In one embodiment, the control logic **201** and algorithm module **205** may determine custom algorithms necessary to communicate with nodes **101** and various storage **117**. For instance, algorithms for communication may be proprietary to certain technological stacks. The control logic **201** and algorithm module **205** may evaluate database operation requests and determine proper nodes **101** to carry out the operation, as well as the storage **117** that need to be accessed for file objects in completing the operation. After determining the nature of the database operation requests and communication required of the requests, the control logic **201** and algorithm module **205** may select or employ the relevant custom algorithms to coordinate traffic between the operating system layer **103** and storage layer **115**.

In one embodiment, the control logic **201** and update module **207** may determine completed database operations and update metadata in the GSI **113** based on the completed operations. Furthermore, the control logic **201** and update module **207** may update storage instances local to nodes **101**, where the control logic **201** and update module **207** may update, for example, metadata for a file from an operation. Likewise, the control logic **201** and update module **207** may further update a storage level extent that stores a storage block, for example, on a local disk of a server. In other words, the control logic **201** and update module **207** may update a storage block in the storage layer **115** based on a transaction completed using a file in the storage layer **115**, and also update metadata associated with the file at a local storage instance on a node **101** that may access the block at storage layer **115**. As previously discussed, the GSI **113** may also update its own metadata repository so that the GSI **113** in some cases may access the block at storage layer **115** without going through a local storage instance.

In one embodiment, the control logic **201** and rebalance module **209** may determine storage extents for all the nodes **101** in a cluster (e.g. nodes **101** at operating system layer **103**). For example, the control logic **201** and rebalance module **209** may take inventory of nodes **101** and associated local storage instances at each of the nodes **101**. Then, the control logic **201** and rebalance module **209** may update the local metadata at the local storage instances to account for a completed transaction. Furthermore, the control logic **201** and rebalance module **209** may perform a logical structure-related operation at the storage layer **115**. For example, the control logic **201** and rebalance module **209** may determine where a command to create a logical structure is issued at the operating system layer **103** and then prompt one or more components for storage **117***a*-**117***n* to create the logical structure. In one embodiment, the control logic **201** and rebalance module **209** may communicate with storage **117***a*-**117***n* remote from nodes **101** or add and remove storage **117** to accommodate requests at the operating system layer **103**.

FIG. **2**B is a diagram **220** of a rebalance module capable of allocating storage space for a cluster of nodes, according to one embodiment. Rebalance module **209** may comprise computing hardware (such as described with respect to FIG. **11**), as well as include one or more components configured to execute the processes described herein for providing the processing services of system **100**. In one implementation, the rebalance module **209** contains control logic **221**, a file locator module **223**, an extents module **225**, availability module **227**, and local update module **229**. The control logic **221** performs control logic functions and facilitates coordination among the other components of rebalance module **209**.

In one embodiment, the control logic **221** and file locator module **223** may receive a logical structure command from one of the nodes **101**. In one instance, the logical structure command may come, more specifically, from a local storage instance on one of the nodes **101**. Then, the control logic **221** may recognize a command as a logical structure command and work with file locator module **223** to check for information regarding location of a file associated with the command. For instance, the control logic **221** and file locator module **223** may check local storage instances for information associated with finding a file object within the storage layer **115**.

Then, the control logic **221** and extents module **225** may look for storage extents in the storage layer **115** or clusters of storage **117**. For instance, control logic **221** and extents module **225** may recognize that certain commands should be directed to particular cluster of storage **117**. In another case, control logic **221** and extents module **225** may check for storage contents in the entire storage layer **115**. In one embodiment, the control logic **221** and extents module **225** may determine from control logic **201** that the operation requested by the logical structure command is complete.

Once the operation is complete, the control logic **221** and availability module **227** may determine the availability of storage space in nodes **101** and storage **117**. For example, the control logic **221** and availability module **227** may determine where some existing space is underutilized and route data storage to that space, rather than prompting addition of storage space. In another embodiment, the control logic **221** and availability module **227** may determine that a particular system has too much space. Then, the control logic **221** and availability module **227** may permit another system to access the space, and/or remove the space. In a more focused case, the control logic **221** and availability module **227** may simply determine if storage is sufficient for an operation.

In one embodiment, the control logic **221** and local update module **229** may update metadata and local metadata to account for the operation completion and possible rebalancing done by the control logic **221** and availability module **227**. For example, actions performed by the control logic **221** and availability module **227** may mean that new directories must be created for new storage paths. The control logic **221** and local update module **229** may recognize and/or create metadata at both (or either) nodes **101** and/or the GSI **113**. For example, the control logic **221** and local update module **229** may have a set of metadata for the operation completion local to respective nodes **101** and another set of metadata for the GSI **113**.

FIG. **3**A is a flowchart **300** of providing unified technological stack management (e.g., via a global storage instance) where metadata is delocalized from storage nodes, according to one embodiment. In step **301**, the control logic **201** may create a global storage instance wherein the global storage instance contains metadata for a storage layer including a plurality of storage nodes, and wherein the global storage instance is delocalized from the plurality of storage nodes. In one embodiment, the process of flowchart **300** may further include designating the global storage instance as a master of one or more local storage instances associated respectively with the plurality of storage nodes (step **303**). For instance, local storage instances may reside of nodes **101** along with databases at the nodes for storage. The control logic **201** may configure the global storage instance created in step **301** such that the global storage instance receives requests from local storage instances, then updates local metadata at local storage instances after completion of the request. In this way, the global storage instance may act as a master to slave local storage instances.

In one embodiment, the control logic **201** may receive a database operation request from an operating system layer (step **305**). For example, nodes **101** may reside on an operating system layer. In the case where a global storage instance acts without being part of a master-slave set-up, the global storage instance may communicate directly with databases at storage nodes (e.g., nodes **101**). Where a global storage instance acts as a master, however, the global storage instance may receive the request from local storage instances at the operating system layer. In one embodiment, the control logic **201** may mediate the database operation request between the operating system layer and the storage layer using the global storage instance (step **307**). The details of mediating the database operation request are part of the flowcharts that follow. In one embodiment, the storage layer spans a plurality of data centers, a plurality of geographic locations, or a combination thereof.

FIG. **3**B is a flowchart **320** of mediating the database operation request between the operating system layer and the storage layer using the global storage instance, according to one embodiment. In one embodiment, the control logic **201** may determine completion of the database operation request (step **321**). For instance, the control logic **201** may determine from nodes **101** that the operation requested has been completed successfully. Then, the control logic **201** may determine one or more storage nodes that completed the database operation request (step **323**). For example, the control logic **201** may determine nodes **101** and corresponding nodes **101** associated with file objects used in performing the requested database operation. Then, the control logic **201** may cause one or more updates to the metadata based on metadata associated with the one or more storage nodes (step **325** and step **327**).

FIG. **3**C is a flowchart **340** of rebalancing storage nodes, according to one embodiment. In one embodiment, the control logic **201** may determine a request to create a storage location (step **341**). For example, the control logic **201** may receive a command related to a logical structure. Then, the control logic **201** may locate nodes **101** at which to create the logical structure. In one embodiment, the control logic **201** may further cause an addition or removal of one or more storage nodes based on the request (step **343**). In one embodiment, the control logic **201** may then determine storage capacity of the plurality of storage nodes and cause a distribution of the metadata across the plurality of storage nodes (step **345** and step **347**). In one embodiment, the control logic **201** may cause the distribution wherein the distribution of the metadata is based on the storage capacity of the plurality of storage nodes. In one embodiment, the control logic **201** may further determine one or more storage configurations related to the storage capacity of the plurality of storage nodes, wherein the distribution of the metadata is based on the one or more storage configurations. For example, the storage nodes and/or global storage instance may have configurable settings. Functions and/or settings at the operating system level **103** may be set to govern storage and usage of the global storage instance in conjunction with storage nodes and the storage layer **115**.

FIG. **4** is a model **400** showing the traditional, client server model for RDBMS architecture, according to one embodiment. For example, a client **401** may initiate a transaction, meaning that a query **403** may be received by an application server **405**. Application server **405** may generate a SQL query and prompt a search **407** at a database **409**. The database **409** would then process the query. For instance, a database engine of database **409** may retrieve the result set for the query and pass the results back to the application server **405**. Then, the application server **405** may pass the result or response **411** to the client **401**.

FIG. **5** is a model **500** where logical or memory components of a database are split from application servers, in one embodiment. In the initial client server model of model **400**, application servers contained logical or memory components of a database. The SQL query was generated directly at the application servers. However, model **500** shows application servers and logical components as separate entities. For example, application servers **501** may exist at one layer and database servers and logical components **503** may exist in an independent layer. Then, the application servers **501** and database servers and logical components **503** may work in conjunction to contact the shared storage system **505**. For instance, application servers **501** may receive a request for a transaction, the database servers and logical components **503** may create the SQL query, and the application servers **501** and/or the database servers and logical components **503** may pass the SQL query to the shared storage system **505**. In separating the database servers and logical components **503** from the application servers **501**, model **500** clusters the logical components. In doing so, model **500** permits processes to run on multiple servers. Since memory structures can then run on multiple machines within the shared storage system **505**, even if one of the application servers **501** was unavailable, other application servers could complete the action. Once one of the servers becomes available, it is able to synchronize its information with other servers and continue acting as part of the cluster.

FIG. **6**A is a model **600** showing storage instance clustering, according to one embodiment. Model **600** is a development from model **500** in that model **600** releases nodes from dependence on shared storage within a single data center. Model **600** achieves this by enabling communication between each node and its operating system, then capturing operating system-related metadata and communicating with storage using the metadata. In other words, model **600** has components devoted specifically to capturing operating-system metadata. For example, several nodes **601***a*-**601***c* (or nodes **601**) may exist, where each database and storage management component (SMC) exists at each node. For instance, node **601***a* may comprise database **603***a* and storage management component **605***a*. In one embodiment, storage management components **605***a*-**605***c* (or storage management components **605**) may comprise algorithms and metadata to manage files. For example, the metadata may contain information to locate file objects. Algorithms may employ metadata to find files at file object locations at storage mediums **607***a*-**607***f*. For example, the algorithms may collect and group metadata to determine a given storage medium **607***a* where collected metadata is grouped. To retrieve file objects, algorithms may identify files required for a transaction, determine metadata to locate the files in storage, and fetch the file objects. Algorithms may further manage or organize metadata, determining metadata that may be associated with each of the nodes **601**. In one embodiment, storage management components **605** may manage file systems and volumes of respective databases **603** and direct SQL statements to proper files. In one embodiment, storage mediums **607***a*-**607***f* (or storage mediums **607**) may contain the actual files. In one instance, the storage mediums **607** may be organized into diskgroups **609***a* and **609***b* (or diskgroups **609**). Diskgroups **609** may be organized around types of storage mediums **607**, for example, storage mediums **607** that share the same configurations. Diskgroups **609** may be any number of storage mediums **607** that may be controlled as one unit.

In one embodiment, the storage management components **605** may create extents for SQL statements at nodes **601**. Extents may comprise units of storage in the storage management components **605** that are allocated for reserved for files and data. In one instance, the smallest units of storage space in storage management components **605** are data blocks. Extents comprise a set number of continuous data blocks reserved for storing the SQL statements. In creating extents, the storage management components **605** may first create an initial extent made up of the set number of continuous data blocks. If the initial extent is full, new extents may be created. These subsequent extents may be of a same size or larger size than the initial extent. Then, the storage management components **605** may distribute the extents across storage mediums **607** in a given diskgroup **609**. In one embodiment, the storage management components **605** may create and/or remove storage mediums **607** within diskgroups **609** or move data between storage mediums **607** within diskgroups **609**. Creating storage mediums **607** may be desired when more storage is necessary and/or when storage medium failure is detected and storage mediums **607** have to be replaced. To create storage mediums **607**, users may configure storage mediums **607** by specifying values for parameters that dictate how to access, efficiently store, and locate data within the storage mediums **607**. To replace storage mediums **607**, a given storage medium **607** may be detached from diskgroup **609***a*, then replaced with a new disk. In one instance, removal of a storage medium **607** may be desirable to delete unused disks that do not have subdisks. In one example, removing a storage medium **607** from a diskgroup **609** may involve disabling the diskgoup **609** and consolidating, for instance, portions of the storage medium **607***a* onto another storage medium **607***b* then removing the original storage medium **607***a*. In another instance, removal may be performed by copying the data on the storage mediums **607** (to back it up), then reconfiguring the number of storage mediums **607** within a given diskgroup **609**. As shown in FIG. **6**A, model **600** is comprised, for example, of two layers: a layer of nodes **601** communicating with a layer of storage, diskgroups **609**.

FIG. **6**B is a flowchart **620** of a communication amongst the layers in model **600**, according to one embodiment. For example, the nodes **601** may receive a database request at step **621**. This means that a local storage instance (SI) located on a particular node **601** may receive the database request (step **623**). In one scenario, the storage management components **605** at each node may be a local storage instance. In other words, the SI is local to each node **601** in a cluster, where the SI may manage communication for the node, with diskgroups **609**. After receiving the database request, the SI may carry out step **625** by communicating with an operating system, for instance, in conjunction with respective databases **603**. In communicating with the operating system, the SI may determine an action to be performed using the diskgroups **609**, depending on the nature of the request. With this action, the SI may communicate with the diskgroups **609**, which may comprise a storage layer (step **627**). The communication may cause completion of the action (step **629**), at which point, the SIs may update the metadata across all the nodes **601** and (local) SIs in a cluster of nodes **601** (step **631**). This way, all of the SIs in a cluster of nodes **601** are synchronized.

The nodes are synchronized so that corresponding nodes are aware of file indexes of nodes within a cluster, and metadata of associated nodes can be managed collectively. However, because metadata is local to each node, model **600** still encounters issues in scaling beyond a data center. Nodes **601** must be in close vicinity to each other and connected via high speed to have the latest information coordinated amongst the nodes **601**. Latency is an issue if nodes **601** are not proximate each other since there would be lags in both communication amongst nodes **601**, and between nodes **601** and diskgroups **609**.

FIG. **7**A is a model **700** showing use of a global storage instance (GSI), according to one embodiment. In one embodiment, model **700** is analogous to GSI **113** of system **100** in FIG. **1**. Like model **600**, model **700** may contain several nodes **701***a*-**701***c* (or nodes **701**), each with respective databases **703***a*-**703***c* (or databases **703**) and storage management components **705***a*-**705***c* (or storage management components **705**). Also like model **600**, model **700** may have a storage layer with storage mediums **707***a*-**707***f* (or storage mediums **707**) organized into diskgroups **709***a* and **709***b* (or diskgroups **709**). However, model **700** includes GSI **711**. In one embodiment, GSI **711** contains metadata for all the nodes **701**. For example, metadata may include information for locating nodes, finding file content, storage extents of records, and/or database pointers. In other words, the metadata contained in GSI **711** may be any information necessary to locate and retrieve file content from nodes. In one instance, GSI **711** may simply perform the function of storage management components **705**. In another instance, GSI **711** may operate in a master-slave model with the storage management components **705**, where the GSI conducts the communication between the nodes **701** and diskgroups **709** by identifying which storage management components **705** to contact and being the initiator to direct commands to update and/or synchronize metadata to the storage management components **705**. For example, based on metadata in GSI **711**, the GSI **711** may determine that file content resides on a particular storage management component **705**.

FIG. **7**B is a flowchart **720** of a communication amongst the layers in model **700**, according to one embodiment. For example, step **721** may include nodes **701** may receive a database request. Then, an SI (e.g., a storage management component **705** at a node) may pass the request to GSI **711** (step **723**). The GSI **711** may evaluate the request (step **725**) and then communicate with the operating system via custom algorithms (step **727**). For instance, the GSI **711** may use custom algorithms specific to interfacing with particular nodes **701** and/or versions of operating systems existing on the particular nodes **701**. Custom algorithms may include any set of heuristics and/or calculations that permits the GSI **711** to communicate with nodes **701**. For example, the custom algorithms may convert communications to a common medium that can be read by both GSI **711** and/or nodes **701**. The custom algorithms may take into account respective specifications and communications means of GSI **711** and nodes **701**, then form a set of rules that can permit interaction between the GSI **711** and nodes **701**.

After ascertaining the action requested, the GSI **711** may communicate with the storage layer (e.g., diskgroups **709**), also via custom algorithms (step **729**). In one embodiment, the GSI **711** may note the completion of the action with step **731**, then update metadata. For example, the GSI **711** may note completion through a permanent change to the storage layer. Failure to complete the action may manifest as a return of the storage layer to a prior state. Permanent change to the storage layer is shown in a visible indication of the transaction in all the resources engaged by the transaction. The change shown through all the resources may affect metadata used to locate those resources in storage or that are part of the storage layer. In this way, GSI **711** may update metadata at the nodes **701** to reflect the change in the storage layer in order to locate the resources in accordance with the change. With model **700**, step **733** of updating metadata may include updating metadata in the GSI **711** and updating metadata at local SIs, for example, via custom algorithms.

FIG. **7**C is a flowchart **740** of a communication amongst the layers in model **700** that leads to creation of a storage location, according to one embodiment. In one embodiment, the creation may take place at databases **703** of nodes **701** associated with an action. For example, data is typically in either a database memory (at a node) or on storage mediums. Until an action (or user transaction) is committed, data is held in the database memory. This may be shown with step **741**, where a user transaction is initiated. To ensure that a database may be returned to a prior state before the transaction is entirely complete, the system in model **700** may take step **743** of setting a savepoint. Then, data from storage mediums may be held in database memories with step **745**, where the data is inserted into a database "A." If the transaction succeeds, a further insert may be made with the data (step **747**). In one embodiment, the insert may be at a storage medium within a diskgroup. Here, the second change with the data is denoted as an insert to an entity "B." If that, too, succeeds and the transaction is complete, the transaction is committed (step **749**). In one embodiment, once a transaction is committed, a log writer writes log information for the transaction. In some cases, commit is not considered complete until the log information is complete.

In one embodiment, if performing the transaction is unsuccessful at any point, step **751** may occur to rollback to the savepoint set in step **743**. In a further embodiment, completion of a transaction may include inserting an error log (step **753**). After the commit, databases may update metadata and associated storage level extent. The commit may correspond to metadata updates, both in flowcharts **620** and **720**. For instance, the system **100** may recognize where a relevant block for the data is stored. Whenever the block is retrieved or updated, system **100** may check associated metadata and update and/or modify the corresponding block. In one case, a storage block could be located on a storage area network (SAN) or local disk of a server.

FIG. **8**A is a diagram **800** of a global storage instance as a centralized form of managing a technology stack, according to one embodiment. In one embodiment, the global storage instance may include multiple metadata sets **801** and blocks **803**. Previously with model **600**, each node **601***a*-**601***c* had its own set of metadata and each node **601***a*-**601***c* managed respective metadata locally. For example, if node **601***a* received a transaction that resulted in a commit, metadata in database **603***a* and storage management component **605***a* would get updated. A commit function ends a transaction, applying the transaction request to a database so that the transaction is recorded in storage. If a storage block associated with the transaction was to be retrieved again, nodes **601** in the cluster would know the location of the block and act accordingly. However, nodes **601** rely on being in close proximity to know which node **601***a*-**601***c* (and associated database **603***a*-**603***c* and storage management component **605***a*-**605***c*) to contact for the block.

By use of the global storage instance of diagram **800**, however, the GSI of diagram **800** may store the database and metadata of all the nodes in a cluster (e.g., metadata sets **801**), as well as storage blocks **803**. Therefore, when a transaction is deemed complete, the GSI of diagram **800** may check for storage management components associated with nodes that executed the transaction. In one embodiment, nodes associated with the transaction may not be local to a cluster. For example, nodes may or may not be within the same data center. Then, metadata is current in the GSI and metadata may permit nodes to interact independently of their geographic locations.

FIG. **8**B is a flowchart **820** of a GSI operating as a master instance, with local SIs as slave instances to the GSI, according to one embodiment. For example, step **821** may include a node receiving a database operation request. An operating system may compute the request at a database memory with step **823** and subsequently send a request to a

GSI to locate a local storage block that can perform the request (step **825**). Then, the GSI may communicate with the operating system to locate metadata to find file objects for the request (step **827**). If the transaction is completed successfully, the GSI may perform step **829** of updating its storage block to process the commit. As a final step, the GSI may synchronize all buffers that are changed as a result of the transaction (step **831**). For instance, the GSI may synchronize database buffers, relevant parts of operating systems, and associated storage blocks.

FIG. **9**A is a flowchart **900** of a storage management operation that takes place in conjunction with the synchronization and updating discussed above, according to one embodiment. Flowchart **900** is one example of single-instance storage management (e.g., model **400**). For example, flowchart **900** shows the operation for a database (DB) server running on a single host in a local storage similar to the scenario shown in model **600**. Most logical structure management operations comprise of creating, dropping, adding, or resizing a datafile. This operation may take place at all layers of communication within an RDBMS (e.g., database, operating system, and storage levels). For flowchart **900**, the database may receive a command related to a logical structure at step **901**. Then, the database may check its metadata repository to locate corresponding storage extents (step **903**). For example, storage extents may be located on a disk. From there, the database may manage files (step **905**). For example, the database may create each datafile as a result of database operations. Then, the database may update metadata associated with datafiles. While file usage and/or management is in flux, the database may employ one or more logical volumes (LV) for the datafile and metadata (step **907**). In one embodiment, the steps of flowchart **900** may further include step **909** of contacting a volume group to access physical volumes (PV) at, for example, disks (step **911**).

FIG. **9**B is a diagram **920** of multi-instance management (e.g., model **600**), according to one embodiment. For example, a cluster **921** may comprise multiple nodes **923**. Local (storage) instances **925** may manage interaction between associated databases, an operating system, and storage. If a logical structure-related command **927** is issued on any node **923** in the cluster **921**, a database **929** may check its metadata in conjunction with a local instance **925**. The local instance **925** may then communicate with the operating system and check for metadata associated with a particular file involved. Once the metadata is updated, storage operations are performed and the local instance **925** is rebalanced across all the nodes in a given cluster. Since management is local to a server, coordination within the cluster is dependent on a high speed network to keep the rebalancing current. As previously discussed, the coordination also requires geographic proximity between the nodes.

FIG. **9**C is a diagram **940** showing use of global instance storage management (e.g., model **700**), according to one embodiment. In one embodiment, the GSI **941** may oversee all the activity for nodes **943** in a cluster. For example, after a logical structure command **945** is issued on a node **943** and a database **947** on the node checks its metadata with local instance **949**. Then, the local instance **949** may check for metadata associated with the requested file and pass the information to the GSI **941**. The GSI **941** has the metadata and knows related local instances **949** of the entire technology stack. When the request is passed to the GSI **941**, the GSI may check for storage extents for the entire storage cluster **951** and perform a logical structure-related operation at the storage layer. A logical structure-related operation may include a management function that allows creating, tracking, and finding storage extents. Tracking storage extents may further include noting that storage extents are available or making storage extents available. Once the transaction is complete, the GSI **941** may rebalance all the nodes **943** within the cluster and update local instance **949** for local metadata. Rebalancing all the nodes **943** may allow allocation of action execution across various nodes. For instance, rebalancing may permit the nodes **943** to be used equally so means to access to file objects associated with transactions is evenly distributed across all the nodes **943**. Updating local instance **949** with local metadata may allow accuracy at local instances **949** when local instances **949** check for metadata associated with requested files before passing information to the GSI **941**. In other words, local instances **949** are updated to facilitate the GSI **941** in finding storage extents in the storage cluster **951**. In other words, the GSI **941** may act as a master node, holding all the information of metadata for all the nodes **943** within a cluster. In delocalizing the metadata and working in a master-slave model with local instances **949**, the GSI **941** may overcome limitations that require clusters to have geographically proximate nodes.

The processes described herein for providing for providing a metadata management framework may be implemented via software, hardware (e.g., general processor, Digital Signal Processing (DSP) chip, an Application Specific Integrated Circuit (ASIC), Field Programmable Gate Arrays (FPGAs), etc.), firmware or a combination thereof. Such exemplary hardware for performing the described functions is detailed below.

FIG. **10** is a diagram of a computer system that can be used to implement various embodiments. The computer system **1000** includes a bus **1001** or other communication mechanism for communicating information and a processor **1003** coupled to the bus **1001** for processing information. The computer system **1000** also includes main memory **1005**, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus **1001** for storing information and instructions to be executed by the processor **1003**. Main memory **1005** can also be used for storing temporary variables or other intermediate information during execution of instructions by the processor **1003**. The computer system **1000** may further include a read only memory (ROM) **1007** or other static storage device coupled to the bus **1001** for storing static information and instructions for the processor **1003**. A storage device **1009**, such as a magnetic disk or optical disk, is coupled to the bus **1001** for persistently storing information and instructions.

The computer system **1000** may be coupled via the bus **1001** to a display **1011**, such as a cathode ray tube (CRT), liquid crystal display, active matrix display, or plasma display, for displaying information to a computer user. An input device **1013**, such as a keyboard including alphanumeric and other keys, is coupled to the bus **1001** for communicating information and command selections to the processor **1003**. Another type of user input device is a cursor control **1015**, such as a mouse, a trackball, or cursor direction keys, for communicating direction information and command selections to the processor **1003** and for controlling cursor movement on the display **1011**.

According to an embodiment of the invention, the processes described herein are performed by the computer system **1000**, in response to the processor **1003** executing an arrangement of instructions contained in main memory **1005**. Such instructions can be read into main memory **1005** from another computer-readable medium, such as the storage device **1009**. Execution of the arrangement of instructions contained in main memory **1005** causes the processor **1003** to perform the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the instructions contained in main memory **1005**. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the embodiment of the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

The computer system **1000** also includes a communication interface **1017** coupled to bus **1001**. The communication interface **1017** provides a two-way data communication coupling to a network link **1019** connected to a local network **1021**. For example, the communication interface **1017** may be a digital subscriber line (DSL) card or modem, an integrated services digital network (ISDN) card, a cable modem, a telephone modem, or any other communication interface to provide a data communication connection to a corresponding type of communication line. As another example, communication interface **1017** may be a local area network (LAN) card (e.g. for Ethernet™ or an Asynchronous Transfer Mode (ATM) network) to provide a data communication connection to a compatible LAN. Wireless links can also be implemented. In any such implementation, communication interface **1017** sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information. Further, the communication interface **1017** can include peripheral interface devices, such as a Universal Serial Bus (USB) interface, a PCMCIA (Personal Computer Memory Card International Association) interface, etc. Although a single communication interface **1017** is depicted in FIG. **10**, multiple communication interfaces can also be employed.

The network link **1019** typically provides data communication through one or more networks to other data devices. For example, the network link **1019** may provide a connection through local network **1021** to a host computer **1023**, which has connectivity to a network **1025** (e.g. a wide area network (WAN) or the global packet data communication network now commonly referred to as the "Internet") or to data equipment operated by a service provider. The local network **1021** and the network **1025** both use electrical, electromagnetic, or optical signals to convey information and instructions. The signals through the various networks and the signals on the network link **1019** and through the communication interface **1017**, which communicate digital data with the computer system **1000**, are exemplary forms of carrier waves bearing the information and instructions.

The computer system **1000** can send messages and receive data, including program code, through the network(s), the network link **1019**, and the communication interface **1017**. In the Internet example, a server (not shown) might transmit requested code belonging to an application program for implementing an embodiment of the invention through the network **1025**, the local network **1021** and the communication interface **1017**. The processor **1003** may execute the transmitted code while being received and/or store the code in the storage device **1009**, or other non-volatile storage for later execution. In this manner, the computer system **1000** may obtain application code in the form of a carrier wave.

The term "computer-readable medium" as used herein refers to any medium that participates in providing instructions to the processor **1003** for execution. Such a medium may take many forms, including but not limited to non-volatile media, volatile media, and transmission media. Non-volatile media include, for example, optical or magnetic disks, such as the storage device **1009**. Volatile media include dynamic memory, such as main memory **1005**. Transmission media include coaxial cables, copper wire and fiber optics, including the wires that comprise the bus **1001**. Transmission media can also take the form of acoustic, optical, or electromagnetic waves, such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, CDRW, DVD, any other optical medium, punch cards, paper tape, optical mark sheets, any other physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave, or any other medium from which a computer can read.

Various forms of computer-readable media may be involved in providing instructions to a processor for execution. For example, the instructions for carrying out at least part of the embodiments of the invention may initially be borne on a magnetic disk of a remote computer. In such a scenario, the remote computer loads the instructions into main memory and sends the instructions over a telephone line using a modem. A modem of a local computer system receives the data on the telephone line and uses an infrared transmitter to convert the data to an infrared signal and transmit the infrared signal to a portable computing device, such as a personal digital assistant (PDA) or a laptop. An infrared detector on the portable computing device receives the information and instructions borne by the infrared signal and places the data on a bus. The bus conveys the data to main memory, from which a processor retrieves and executes the instructions. The instructions received by main memory can optionally be stored on storage device either before or after execution by processor.

FIG. **11** illustrates a chip set **1100** upon which an embodiment of the invention may be implemented. Chip set **1100** is programmed to present a slideshow as described herein and includes, for instance, the processor and memory components described with respect to FIG. **10** incorporated in one or more physical packages (e.g., chips). By way of example, a physical package includes an arrangement of one or more materials, components, and/or wires on a structural assembly (e.g., a baseboard) to provide one or more characteristics such as physical strength, conservation of size, and/or limitation of electrical interaction. It is contemplated that in certain embodiments the chip set can be implemented in a single chip. Chip set **1100**, or a portion thereof, constitutes a means for performing one or more steps of FIGS. **4-7**.

In one embodiment, the chip set **1100** includes a communication mechanism such as a bus **1101** for passing information among the components of the chip set **1100**. A processor **1103** has connectivity to the bus **1101** to execute instructions and process information stored in, for example, a memory **1105**. The processor **1103** may include one or more processing cores with each core configured to perform independently. A multi-core processor enables multiprocessing within a single physical package. Examples of a multi-core processor include two, four, eight, or greater numbers of processing cores. Alternatively or in addition, the processor **1103** may include one or more microprocessors configured in tandem via the bus **1101** to enable independent execution of instructions, pipelining, and multithreading. The processor **1103** may also be accompanied with one or more specialized components to perform certain processing functions and tasks such as one or more digital signal processors (DSP) **1107**, or one or more application-specific integrated circuits (ASIC) **1109**. A DSP **1107** typically is configured to process real-world signals (e.g., sound) in real time independently of the processor **1103**. Similarly, an ASIC **1109** can be configured to performed specialized functions not easily performed by a general purposed processor. Other specialized components to aid in performing the inventive functions described herein include one or more field programmable gate arrays (FPGA) (not shown), one or more controllers (not shown), or one or more other special-purpose computer chips.

The processor **1103** and accompanying components have connectivity to the memory **1105** via the bus **1101**. The memory **1105** includes both dynamic memory (e.g., RAM, magnetic disk, writable optical disk, etc.) and static memory (e.g., ROM, CD-ROM, etc.) for storing executable instructions that when executed perform the inventive steps described herein to controlling a set-top box based on device events. The memory **1105** also stores the data associated with or generated by the execution of the inventive steps.

While certain exemplary embodiments and implementations have been described herein, other embodiments and modifications will be apparent from this description. Accordingly, the invention is not limited to such embodiments, but rather to the broader scope of the presented claims and various obvious modifications and equivalent arrangements.

While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that the teachings may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all applications, modifications and variations that fall within the true scope of the present teachings. The scope of protection is limited solely by the claims that now follow. That scope is intended and should be interpreted to be as broad as is consistent with the ordinary meaning of the language that is used in the claims when interpreted in light of this specification and the prosecution history that follows and to encompass all structural and functional equivalents. Notwithstanding, none of the claims are intended to embrace subject matter that fails to satisfy the requirement of Sections **101**, **102**, or **103** of the Patent Act, nor should they be interpreted in such a way. Any unintended embracement of such subject matter is hereby disclaimed.

Except as stated immediately above, nothing that has been stated or illustrated is intended or should be interpreted to cause a dedication of any component, step, feature, object, benefit, advantage, or equivalent to the public, regardless of whether it is or is not recited in the claims.

It will be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein. Relational terms such as first and second and the like may be used solely to distinguish one entity or action from another without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by "a" or "an" does not, without further constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure.

What is claimed is:

1. A method comprising:

creating, by an apparatus operated by a service provider, a global storage instance in response to an end user request, wherein the global storage instance contains metadata of a storage layer including all storage nodes operated by the service provider for a plurality of clients, and wherein the global storage instance is delocalized from the storage nodes, wherein the storage layer includes a plurality of data centers at different geographic locations;

receiving, by the apparatus, a database operation request from an operating system layer;

mediating, by the apparatus, the database operation request between the operating system layer and the storage layer using the metadata of the storage nodes contained in the global storage instance; and

upon a completion of the database operation request, initiating, by the apparatus, (1) updates to the metadata of the storage nodes contained in the global storage instance based on metadata locally updated at one or more of the storage nodes that completed the database operation request, (2) a synchronization of file indexes of all of the storage nodes, and (3) an account for and a rebalance of storage space available in all of the storage nodes.

2. A method of claim **1**, further comprising:

designating the global storage instance as a master of one or more local storage instances associated respectively with the storage nodes,

wherein the end user request is made by a customer and received via a network node operated by the service provider.

3. A method of claim **1**, further comprising:

determining a request to create a storage location; and

causing an addition or removal of one or more storage nodes based on the request.

4. A method of claim **3**, further comprising:

causing a distribution of the metadata across the storage nodes.

5. A method of claim **3**, further comprising:

determining storage capacity of the storage nodes,

wherein the distribution of the metadata is based on the storage capacity of the storage nodes.

6. A method of claim **5**, further comprising:

determining one or more storage configurations related to the storage capacity of the storage nodes; and

wherein the distribution of the metadata is based on the one or more storage configurations.

7. An apparatus comprising:

at least one processor; and

at least one memory including computer program code for one or more programs, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus operated by a service provider to perform at least the following,

create a global storage instance in response to an end user request, wherein the global storage instance contains metadata of a storage layer including all storage nodes operated by the service provider for a plurality of clients, and wherein the global storage instance is delocalized from the storage nodes, wherein the storage layer includes a plurality of data centers at different geographic locations;

receive a database operation request from an operating system layer;

mediate the database operation request between the operating system layer and the storage layer using the metadata of the storage nodes contained in the global storage instance; and

upon a completion of the database operation request, initiate (1) updates to the metadata of the storage nodes contained in the global storage instance based on metadata locally updated at one or more of the storage nodes that completed the database operation request, (2) a synchronization of file indexes of all of the storage nodes, and (3) an account for and a rebalance of storage space available in all of the storage nodes.

8. An apparatus according to claim **7**, wherein the apparatus is further caused to:

designate the global storage instance as a master of one or more local storage instances associated respectively with the storage nodes.

9. An apparatus according to claim **7**, wherein the apparatus is further caused to:

determine a request to create a storage location; and

cause an addition or removal of one or more storage nodes based on the request.

10. An apparatus according to claim **9**, wherein the apparatus is further caused to:

cause a distribution of the metadata across the storage nodes.

11. An apparatus according to claim **9**, wherein the apparatus is further caused to:

determine storage capacity of the storage nodes,

wherein the distribution of the metadata is based on the storage capacity of the storage nodes.

12. An apparatus according to claim **11**, wherein the apparatus is further caused to:

determine one or more storage configurations related to the storage capacity of the storage nodes; and

wherein the distribution of the metadata is based on the one or more storage configurations.

13. A system comprising:

a plurality of storage nodes operated by a service provider for a plurality of clients; and

a platform server configured to create a global storage instance in response to an end user request, wherein the global storage instance contains metadata of a storage layer including all of the storage nodes operated by the service provider for a plurality of clients, and wherein the global storage instance is delocalized from the storage nodes, wherein the storage layer includes a plurality of data centers at different geographic locations; to receive a database operation request from an operating system layer; to mediate the database operation request between the operating system layer and the storage layer using the metadata of the storage nodes contained in the global storage instance; and to initiate (1) updates to the metadata of the storage nodes contained in the global storage instance based on metadata locally updated at one or more of the storage nodes that completed the database operation request, (2) a synchronization of file indexes of all of the storage nodes, and (3) an account for and a rebalance of storage space available in all of the storage nodes, upon a completion of the database operation request.

14. A system according to claim **13**, wherein the platform server is further configured to designate the global storage instance as a master of one or more local storage instances associated respectively with the storage nodes.

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